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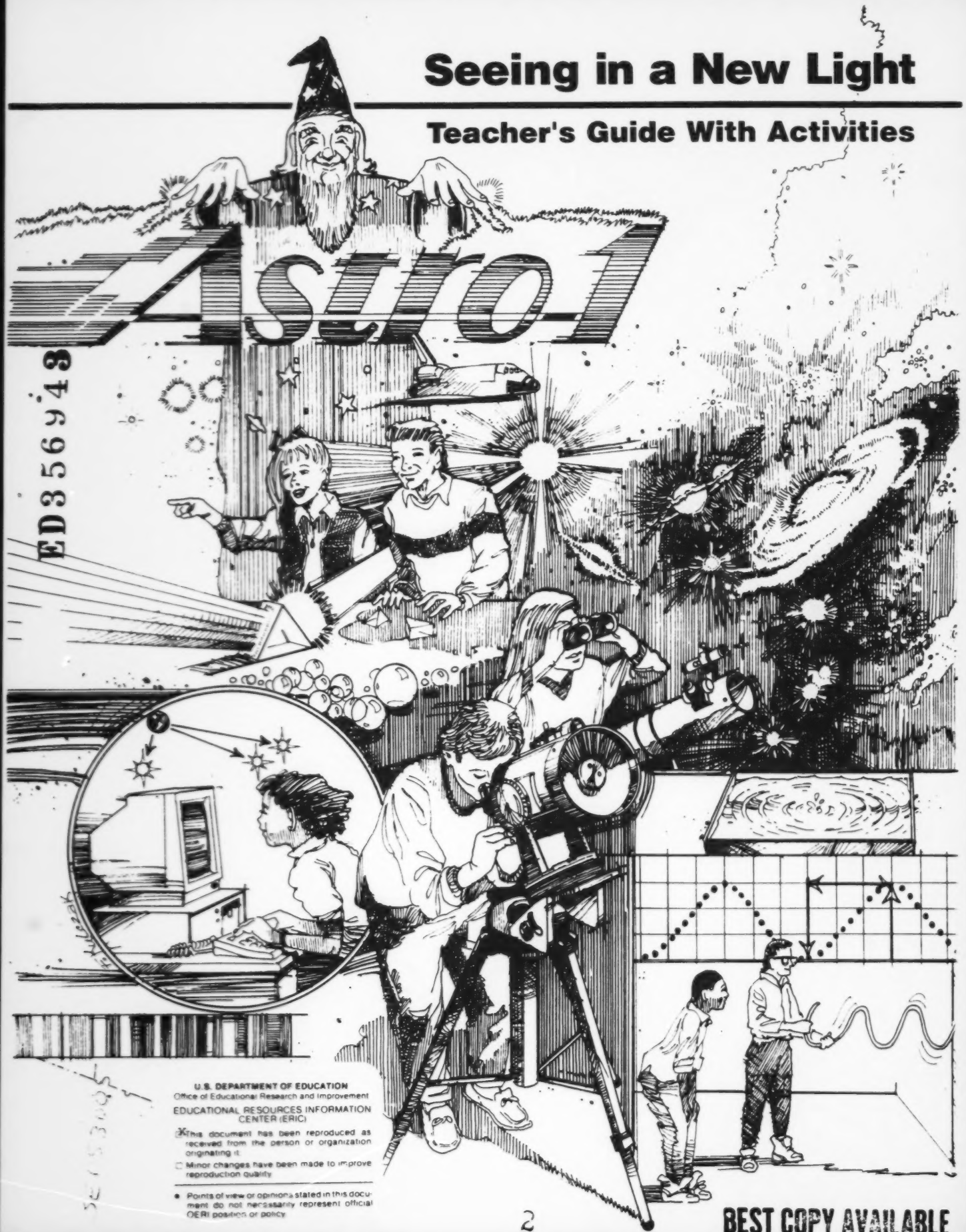
ABSTRACT

For as long as people have walked the Earth, they have looked to the stars, have been inspired by their beauty and remoteness and have found their way over sea and deserts by their guidance. Since then, enormous progress has been made in the understanding of the stars, and today the expanding and fascinating world of high-energy astronomy awaits the student: a world of ultraviolet and X-ray spectrometers and telescopes that explore stars, nebulae, and phenomena like quasars and black holes. This teacher's guide may be used to introduce and summarize lessons that will be taught by the crew of the Astro observatory shuttle mission--the first to be dedicated to astrophysics, the branch of astronomy that investigates the physical characteristics of celestial objects such as their size, mass, temperature, and chemistry. The guide is also a practical source of lesson plans and student activities that may be used by itself to teach scientific principles and to interest students in the field of astronomy. It can supplement sections of texts in Earth science, physical science, or social studies. Many activities are designed to extend into the realms of literature, mathematics, art, and history. The six basic concepts taught in this program are: (1) visible light demonstrates the existence of the spectrum; (2) radiation exists above and below the visible portion of the electromagnetic spectrum; (3) light and other kinds of radiation consist of photons that travel in waves; (4) certain celestial objects give off radiation other than visible light, and must be studied in other energy ranges; (5) certain waves of radiation are blocked by Earth's atmosphere; and (6) astronomers need to place telescopes above Earth's atmosphere to perform astronomical observations in several regions of the spectrum. Background information introduces each activity, materials needed are listed, step-by-step procedures are described, and home activities are suggested. A brief discussion of careers in astronomy, some facts on Astro-1 and the electromagnetic spectrum, lists of resources, and a glossary conclude the document. (PR)

Seeing in a New Light

Teacher's Guide With Activities



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Astro-1 Teacher's Guide With Activities

Seeing in a New Light

January 1990

EP274

National Aeronautics and
Space Administration

Astro-1 Teacher's Guide With Activities

Seeing in a New Light

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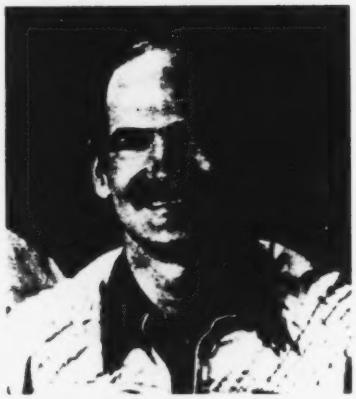

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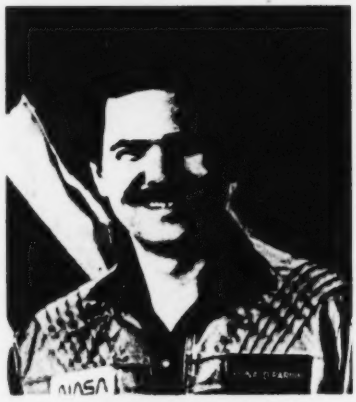

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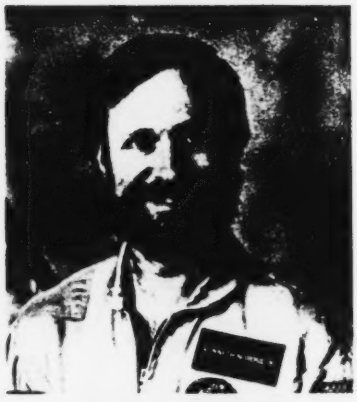

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Preface

We, the crew of the Astro-1 Observatory mission, invite you to join us on a special adventure: NASA's first Shuttle mission dedicated to astrophysics. Astrophysics is the branch of astronomy that investigates the physical characteristics of celestial objects such as their size, mass, temperature, and chemistry. On this mission, the Space Shuttle Columbia will lift three ultraviolet telescopes and one X-ray telescope above the scattering and absorbing effects of Earth's atmosphere so that astronomers in the Shuttle and on the ground can observe some of the Universe's most fascinating objects. Together, we will use complex computers and pointing systems to turn huge telescopes on the stars and analyze their light for information about their structure and chemistry.

We can hardly wait to share the excitement of astronomy in orbit with students and teachers alike.

This Teacher's Guide concentrates on the electromagnetic spectrum, a subject that was chosen because it is part of the middle school curriculum and because an understanding of the different ranges of energy is crucial to an understanding of the high-energy astronomy performed by the Astro-1 telescopes. Other information about the Astro-1 mission is available through the various NASA Educational Resources listed on page 53 of this Teacher's Guide.

This is only the beginning. There will be other science missions in the months to come. We hope you will make us and future Shuttle crews a part of your classrooms as we explain how science is done in orbit.

Come join us in space.

Vance Brand
Commander

Guy Gardner
Pilot

Mike Lounge
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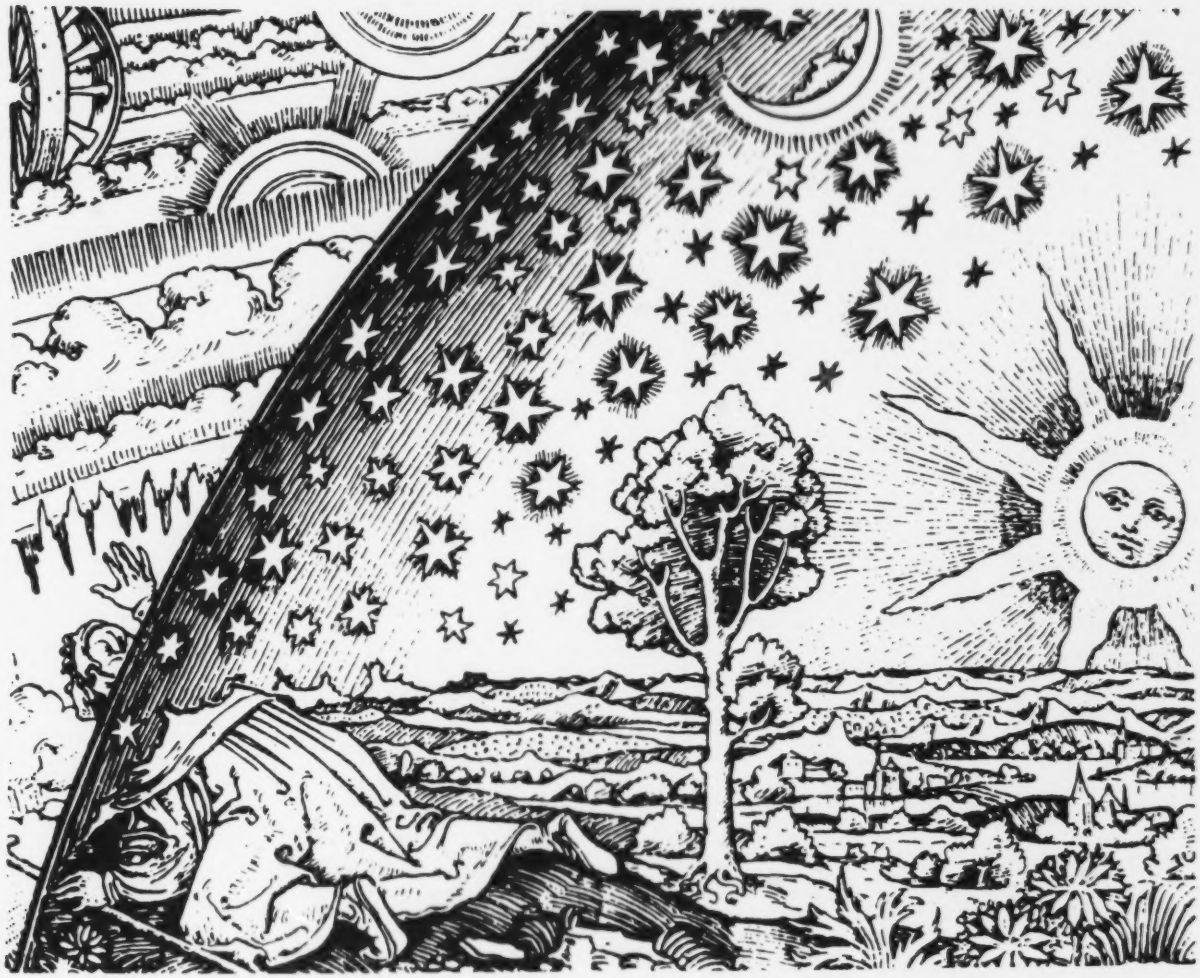


Introduction

For as long as people have walked the Earth, they have looked to the stars. Besides exciting the imagination and inspiring songs and poetry, the stars have provided guidance for many of the advances of civilization. Farmers have sown and harvested crops according to the phases of the Moon and the positions of heavenly bodies. Explorers and sailors have charted their courses across deserts, forests, and open seas with the aid of the stars. Those who studied the stars were sometimes pictured as magical and wise — wizards who tried to understand the remote and beautiful night skies; even today, astronomy embodies both the practical and the romantic, the understandable and the mysterious.

Almost every culture has studied the skies. The Babylonians first grouped the stars into constellations; the Chaldeans and Egyptians used astronomical observations to calculate the length of the year as 365-1/4 days; the Greeks determined the circumference of Earth and catalogued 1,080 stars, grouping them by their brightness. The Greeks also may have been the first to teach that the Sun was the center of the solar system. During the Middle Ages, many of the sciences experienced setbacks, but astronomy was kept alive by the Arabs who translated and preserved the works of the Greeks and improved astronomical instruments. In 1543, Copernicus, a Polish researcher, again advanced the theory that the Sun was the center of the solar system. Kepler, a German mathematician, calculated the movements of the planets and proved Copernicus right. With Galileo's use of a primitive telescope in the 1600s, the science of astronomy took a giant leap forward as more of the Universe was brought into view.

Today's astronomers use giant telescopes, Earth-orbiting satellites, and sophisticated instruments that operate above the atmosphere to explore the Universe. So that progress will continue, students must be made aware of the fascination of astronomy. The goal of this guide is to excite the imagination of students in grades 6, 7, and 8 and encourage them to pursue the study of science, particularly astronomy. To do this, they will be introduced first to the basic scientific principle of the electromagnetic spectrum and to related concepts. As the guide progresses, the concepts become more complex, encompassing the ideas of light waves, their lengths, frequencies, and relationship to color; the effect of the atmosphere on light waves; and the relationship of these concepts to astronomy.

Then, students will be introduced to the Astro Program, a series of Space Shuttle flights that will lift a complement of telescopes above the distorting and absorbing effects of Earth's atmosphere. Astro-1 is scheduled to fly in the spring of 1990.

Astro-1 will carry 4 instruments during its 10-day mission. Three are ultraviolet instruments: the Hopkins Ultraviolet Telescope (HUT) developed at The Johns Hopkins University, the Ultraviolet Imaging Telescope (UIT) developed at Goddard Space Flight Center, and the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) developed at the University of Wisconsin. The fourth instrument is the Broad Band X-Ray Telescope (BBXRT), also developed at Goddard Space Flight Center. With these instruments, astronomers will investigate celestial bodies that emit ultraviolet and X-ray radiation impossible to detect with Earthbound telescopes. Some of these objects are hot, young stars; old, dying stars; quasars; neutron stars; supernova remnants; binary star systems; active galaxies; and maybe even black holes.

This expanding and fascinating world of high-energy astronomy awaits your students: a world of ultraviolet and X-ray spectrometers and telescopes that explore stars, nebulae, and phenomena like quasars and black holes, which were unknown to the ancients and are new even to your students' parents.

This Teacher's Guide may be used to introduce and summarize the lessons that will be taught from space by Astro-1 crew members. It is also a practical source of lesson plans and student activities that may be used by itself to teach scientific principles and to interest students in the field of astronomy. It can supplement sections of texts in Earth science, physical science, or social studies. Many activities are designed to extend into the realms of literature, mathematics, art, and history.

The National Aeronautics and Space Administration (NASA) has chosen a wizard as the logo for this Teacher's Guide in the hope that today's students and teachers, like their ancestors, will discover the mystery, excitement, and importance of astronomy and that students will look to the stars to learn about the Universe.

Instructions for Using the Teacher's Guide

This Teacher's Guide is designed to be used with classes of varied sizes and abilities and can be adapted to different time schedules. It is written for middle school students (grades 6, 7, and 8), but many activities will appeal to younger and older students.

Six basic concepts are taught:

Concept 1: Visible light demonstrates the existence of the spectrum.

Concept 2: Radiation exists above and below the visible portion of the electromagnetic spectrum.

Concept 3: Light and other kinds of radiation consist of photons that travel in waves.

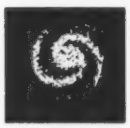
Concept 4: Certain celestial objects give off radiation other than visible light, and we must study them in other energy ranges.

Concept 5: Certain waves of radiation are blocked by Earth's atmosphere.

Concept 6: Astronomers need to place telescopes above Earth's atmosphere to perform astronomical observations in several regions of the spectrum.

These concepts are arranged so that the simpler ideas are presented first. If students are not prepared to work on wavelengths, for example, you may want to cover only Concepts 1 and 2. If your students are well along in studying the electromagnetic spectrum, you may want to begin with Concept 5.

All answers and suggestions for the teacher are printed at the end of each concept, before the Student Activity pages.



Background
This information introduces each concept. Interested students may be referred to some of the references given in the back of this guide.

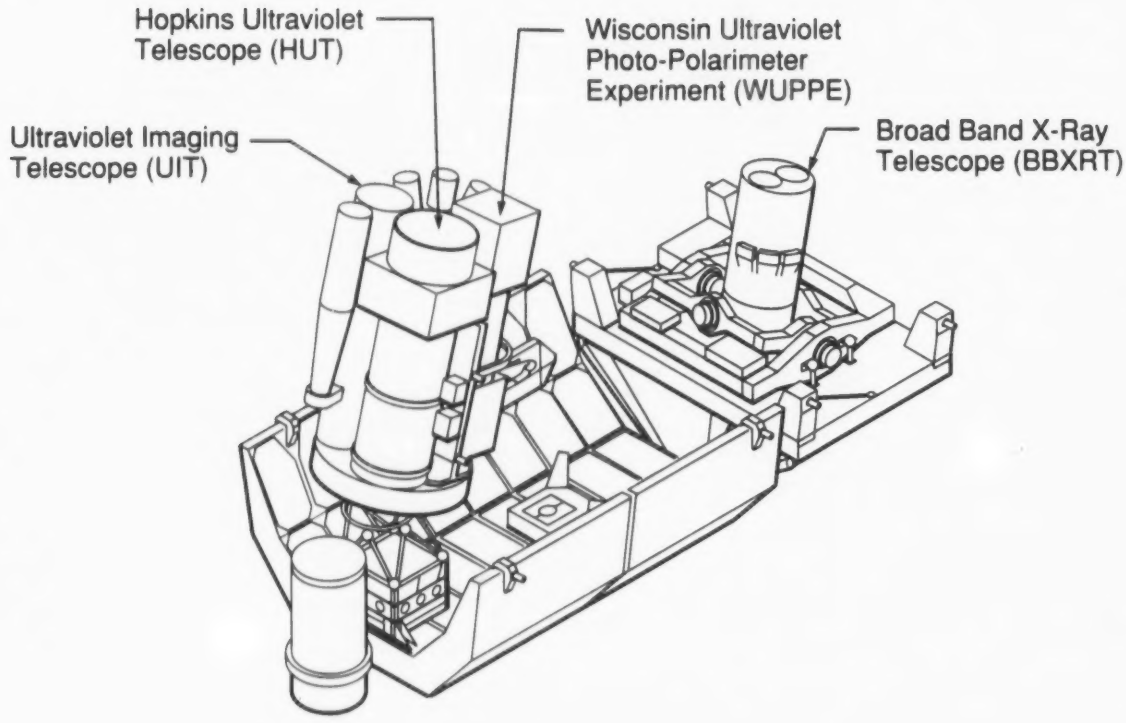
Classroom Activities
You may choose from several classroom activities to teach each concept, depending on the interests and needs of your students. You also may duplicate these and use them as task cards for students working as individuals or in groups.

Options for Extending the Lesson Across the Curriculum
These activities are included to reflect the current emphasis on interdisciplinary learning. They are suggestions, and teachers should use them according to the time available for study, the ability of other teachers to help in team teaching, and student interest.

Home Activities
Assign these lesson extensions after Classroom and Student Activities have been completed. They help students remember what has been learned, are enjoyable supplements to homework, and provide an opportunity for parents to participate.

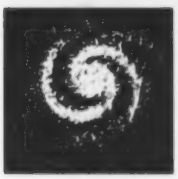
Student Activities
These are intended to be reproduced for independent individual or small-group work.

Your Career in Astronomy
One of the goals of the Astro-1 Teacher's Guide is to encourage students to take an interest in astronomy and perhaps pursue it as a career. This section may be copied for students to read and used for classroom discussion.


Hopkins Ultraviolet Telescope (HUT)
Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE)
Ultraviolet Imaging Telescope (UIT)
Broad Band X-Ray Telescope (BBXRT)

Astro-1 Payload

Seeing the Colors in Light



Background

We often think of rainbows as magical — the subject of charming legends of leprechauns and pots of gold. This makes the rainbow an exciting starting point for the study of the **electromagnetic spectrum**. Think about the colors of the rainbow: red, orange, yellow, green, blue, indigo, and violet. Raindrops break **white light** into its component colors, producing rainbows. This process can be duplicated with a **prism** or a **diffraction grating** or even a pan of water and a mirror.

Activity 1: Producing a Spectrum

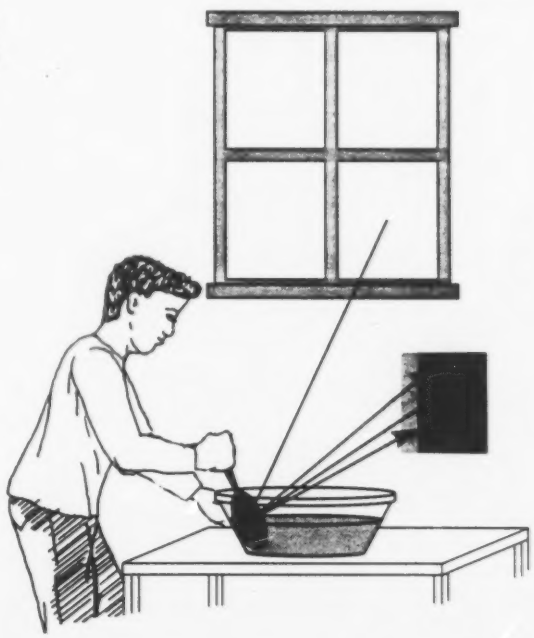
Materials Needed

- pan of water and a small mirror or
- a prism or
- diffraction grating (You may be able to borrow a diffraction grating from a high school physics teacher or remove one from an inexpensive spectroscope.)
- light source, such as sunlight, or
- 1 or 2 straight filament lights with sockets

If you are using the pan of water, set the tray of water in bright sunlight. Lean the mirror against an inside edge of the pan and adjust it so that a spectrum appears on the wall.

If you are using a prism, turn the prism at various angles until a spectrum appears. Adjust carefully until the spectrum is spread out as much as possible.

If you are using a diffraction grating, turn the grating so that the colors are to the right and left of the bulb.



Questions

1. What colors in the spectrum can you name?
2. Are the spectra produced by different diffraction devices the same?
3. What do you think the word "diffraction" means?

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Activity 2: "Bubble-ology"

Materials Needed

The colors of visible light can also be seen in an enjoyable experiment with "bubble-ology."

- 1 gal (4 ℓ) of cold water in a pan or bowl
- 1 C (0.25 ℓ) of liquid dishwashing detergent
- several straws
- light source, such as sunlight, or
- 1 or 2 straight filament lights with sockets

Step 1: In a shallow bowl or pan, gently mix the water and detergent. Use the straws to blow large bubbles in the water.

Step 2: Put the bowl in sunlight and examine the colors appearing on the surface of the bubbles.

When light hits the thin film of a bubble, it is reflected off both the top and bottom surfaces. These two different reflections cross and run into one another. When this happens, the reflected light separates into rainbow colors, also known as "interference color."

As the bubbles grow thinner and their "skin" is stretched out, the colors become redder. Later lessons will help you understand why.

Options for Extending the Lesson Across the Curriculum

Language

Look up the word **spectrum**. The plural used in the questions for Activity 1 is **spectra.** Why would the plural be formed this way? Spectrum is a Latin word and so forms its plural differently. Are there other words that form their plurals this way? What is the origin (etymology) of these words?

Creative Writing

Make up your own rainbow legend and share it with a younger child.

Art

Different colors of light and different colors of paint can both be mixed; however, red, green, and blue combine to form **white light**, while the primary colors of paint (red, yellow, and blue) combine to make **black**. Set up three projectors. Put a red filter on one, a blue filter on another, and a green filter on the last. Project these onto the same area. Where the colors overlap, white light will appear. Now, experiment with red, yellow, and blue paints. Paints have color because they absorb certain frequencies of light and reflect others. Why does black result when all three primary paint colors are mixed?

Home Activities

1. Early in the morning or late in the afternoon, use a hose with a sprayer attachment to create a rainbow in your yard. Use dark trees, bushes, or grass as a background for greater visibility.

2. With a magnifying glass, examine the screen of a television or a color picture from a magazine to see how color is achieved.

3. On a clear, dark night, look carefully at the stars. Color can be found here, too. If you look closely, some stars are noticeably red in color and some are blue-white. The blue-white stars are hotter, and red stars are cooler.

Activity 1 Answers: 1. Because there are no clear divisions between the colors, answers will differ here. This helps introduce the concept of a **continuous spectrum** that has no lines or well-defined boundaries. 2.Yes, basically they are the same. 3. Accept any reasonable answer here: breaking up, bending, splitting, and so on.
Note to Teacher: For science supplies such as prisms and diffraction gratings, see "Where to Obtain Materials," page 56.
Answers for Options for Extending the Lesson Across the Curriculum: Language — Some other words are medium (media), memorandum (memoranda), curriculum (curricula). These words come from the Latin, which does not use "s" to form plurals. Art — Black results because all colors are being absorbed; none are being reflected.
Student Activity Answers: What Color Is Black?: All pigment colors are found in black ink.

Concept 1

Visible light demonstrates the existence of the spectrum.

Student Activity

What Color is Black?

Materials needed

- black felt-tip pen
- strips of coffee filters or clean newsprint
- glass jar
- water
- pencil or tongue depressor
- tape

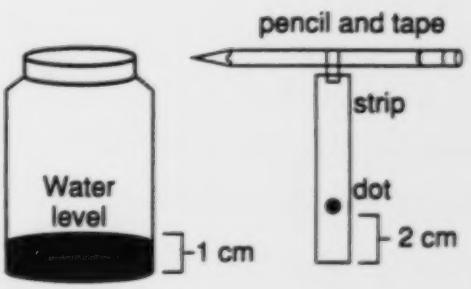
Step 1: Place a dot of black ink from the pen about 1 in. (2 cm) from one end of the paper strip.

Step 2: Tape the other end of the strip to the center of the pencil or tongue depressor.

Step 3: Put water into the jar so that about 0.5 in. (1 cm) of the paper strip will be under water when the pencil is placed on top.

Step 4: What colors do you think will be in the ink? Place a check next to those colors.

Color	Predicted	Actual
black		
red		
green		
blue		
yellow		
orange		
indigo		
violet		



Step 5: Rest the pencil on top of the jar so that the paper is in the water. The dot should **not** be under water.

Step 6: Observe carefully for 5 minutes. Check the colors that actually appear on the strip.

Results

What can be said about the colors in black ink?

Concept 1

Visible light demonstrates the existence of the spectrum.

Student Activity

Colors and Your Mind

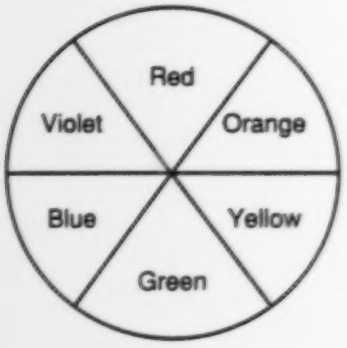
Colors play an important role in our lives, and we make color decisions every day. What color shirt should I put on? What color slacks should I buy?

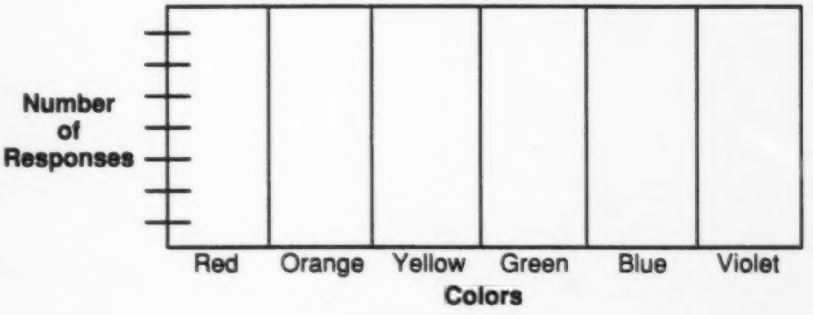
Different people have different color preferences. Do you like the warm reds and oranges or the cool greens and blues? Do color choices change? Do males and females tend to like different colors?

Try doing a survey.

Step 1: Color the wheel below according to the labels. Make the colors as similar as possible in intensity (felt-tip markers are good for this). Make the colors as "true" as possible; that is, make the red a "true red" rather than an orange-red or a blue-red, and so on with the other colors.

Step 2: Ask your friends and teachers to choose a favorite color. Keep track of the results.





Step 3: Fill in the number of responses vertically on the left side of the graph. Remember to use consistent steps: 0, 5, 10, 15 . . . or 0, 10, 20 . . . and so on.

Step 4: You can plot your graph as a line graph or a bar graph. The bar graph might be clearest because you could color your bars accordingly.

Step 5: Share the results with your class. An interesting variation might be to make two or more copies of the graph and survey males and females separately. Is there a difference? Try it again with individuals in different age groups; for example, people under 20 and those over 20. How do these compare?

Concept 1

Visible light demonstrates the existence of the spectrum.

Student Activity

Color Wheels

Color wheels show how our eyes and our brain mix colors. Our eyes receive the reflected colors, but because the colors are changing rapidly, our brain cannot distinguish them, and we see some intermediate color.

Step 1: Using this circle as a guide, trace and cut another circle out of poster board or heavy construction paper.

Step 2: Paint one side yellow and the other side blue.

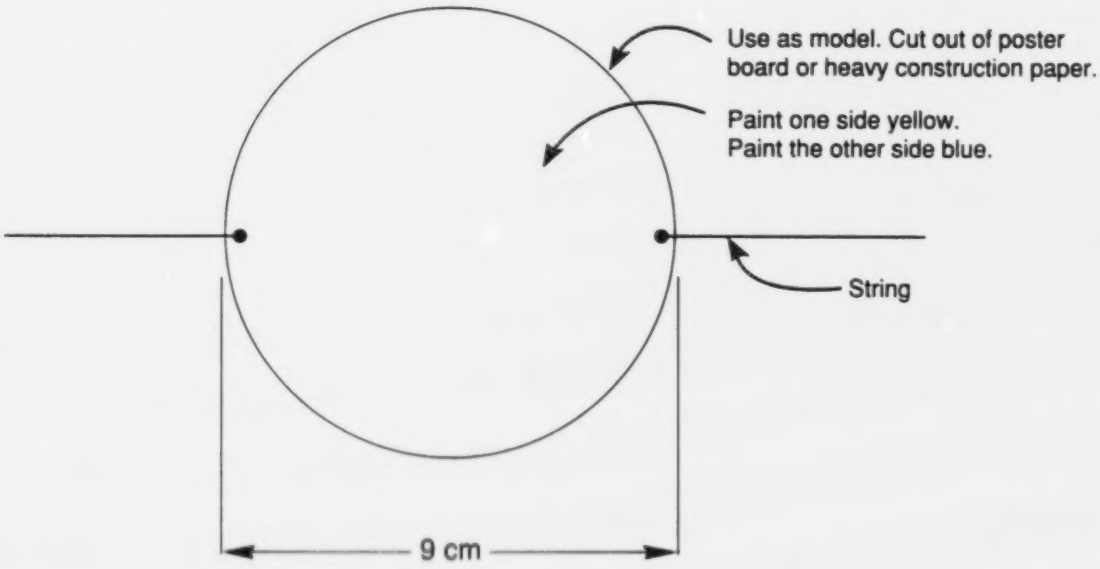
Step 3: Attach strings to opposite sides of the circle.

Step 4: Twirl string so the circle flips rapidly.

Step 5: Try this experiment again with different colors and keep track of the resulting colors.

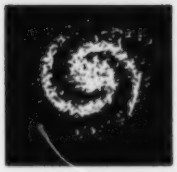
Results

What colors result?


Use as model. Cut out of poster board or heavy construction paper.
Paint one side yellow.
Paint the other side blue.
String
9 cm

Twirl disk strings between fingers and thumb.

Seeing the Invisible



Background

While creating a spectrum is enjoyable, the exciting part is still to come: exploring the spectrum that is invisible.

Have you ever had X-rays taken? What did they look like? What could you see? Did you see the X-rays coming out of the machine? How did you know they were there?

X-rays are part of the spectrum but are invisible. Today, you will prove the existence of invisible radiation. Remember, radiation means energy. These invisible rays are beyond both the red and violet ends of the visible spectrum and were discovered when Johann Ritter proved the existence of **ultraviolet rays** and William Herschel did the same with **infrared radiation**. These activities use almost exactly the same methods that were used in the 1800s when these discoveries were made.

Activity 1: Herschel's Experiment

To demonstrate the existence of infrared radiation, duplicate Herschel's experiment.

Materials Needed

- prism
- light source
- three weather thermometers
- pencil and paper

Step 1: Allow the three thermometers to register the temperature of the air where the experiment will be done — about 5 minutes. Take careful note of the temperatures.

Step 2: Create a spectrum using sunlight as the light source. (See Concept 1.)

Step 3: Place thermometers at several points in the spectrum: one in the violet range, one in the center, and one just barely beyond the red end. Leave the thermometers in the spectrum for at least 5 minutes, moving carefully as the sunlight moves the spectrum. Temperature changes may be very slight, so observe carefully.

Questions

1. What were the final readings on each of the three thermometers?
2. Why would there be an increase in temperature beyond the red end of the spectrum?
3. What does this tell us about what exists beyond the visible red?

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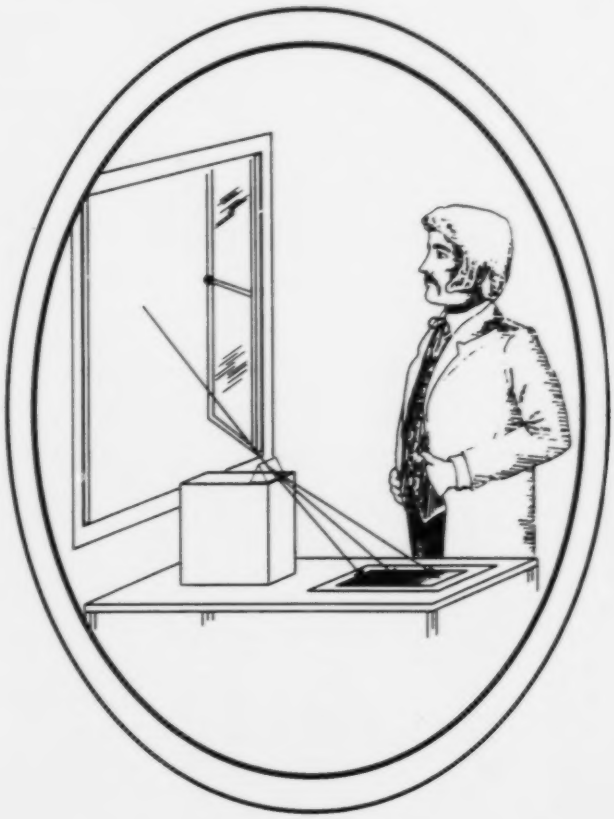
Activity 2: Ritter's Experiment

To demonstrate the existence of ultraviolet radiation, duplicate Ritter's experiment. In 1801, Johann Ritter performed an experiment using paper treated with silver chloride, which decomposes in the presence of light. He found that the silver chloride deteriorated even more rapidly when exposed to the previously unknown radiation beyond the violet end of the spectrum, which the human eye cannot detect.

Materials Needed

- several sheets of blueprint paper
- 1 qt (about 1 ℓ) of household ammonia
- flat pan
- prism or mirror in pan of water
- light source



Step 1: Using a prism or a pan of water, create a spectrum on a horizontal surface, such as a table. Use sunlight from an open window, as glass blocks most ultraviolet radiation. The prism should be resting on a stable object so that the spectrum does not move.

Step 2: Working quickly to prevent exposure of the paper to too much light, cut a piece of blueprint paper about four times larger than the spectrum. Place blueprint paper, which behaves the same way that Ritter's silver chloride paper did, underneath the spectrum. Quickly outline the area covered by the spectrum with a felt-tip pen. Label the violet end.

NOTE: Depending on the sensitivity of the paper, different exposure times will be needed. Most exposure times will be fairly brief, however: about 15 to 20 seconds.

Step 3: Put just enough ammonia in the pan to cover the bottom to a depth of about 0.5 in. (1 cm). In front of an open window or beneath a vent fan, hold the paper over the pan of ammonia so that the fumes will process the paper. Notice the changes in the area outlined and the area just beyond the violet end. You may have noticed that this area began to change even before processing with the ammonia.

Questions

1. What happened to the part of the paper lying where you can see violet?
2. What happened to the part of the paper lying just beyond that violet section?
3. What does this demonstrate about the area beyond the violet end of the spectrum?

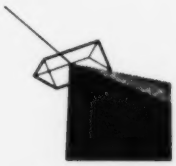
Activity 3: Astro-1 Experiments

Look at the Astro-1 illustrations and Astro-1 Facts your teacher has given you and/or projected onto the wall or a screen.

A NASA mission, named Astro-1, will carry instruments into space that will look at the stars and other objects in invisible energy ranges. Astro-1 instruments will be detecting the ultraviolet and X-ray ranges of the spectrum. Objects in the Universe emit energy in different wavelengths: visible light, infrared rays, ultraviolet waves, and others. The only way scientists can study many of these objects, particularly ones that are billions of light-years away, is to study the energy they give off in different wavelengths.

Question

Why would astronomers want to study ultraviolet radiation and X-rays from far-away objects?



Options for Extending the Lesson Across the Curriculum

Language Arts

Look up the prefix **infra.** What does it mean? Why would **infrared** be called **"below"** red? What does **ultra** mean? What other words can you find or do you know that begin with **ultra**?

Art

Draw or paint your own portrait as your dog or cat would see you, using only combinations of black and white.

Home Activities

Look through your clothes at home. Remember what you learned with the colored cloths and the ice cubes? If you had to select clothes for a trip to the Sahara Desert, what colors would keep you cool? What colors would keep you warm on a trip to the Arctic?

Activity 1 Answers: 1. Answers will vary. 2. Heat must be there. 3. Invisible energy is there that produces heat.
Activity 2 Answers: 1. It shows signs of exposure. 2. It should be even more exposed than the violet section, probably appearing as a lighter area. 3. It demonstrates that radiation is there, but it is not visible to the human eye.
Activity 3 Answer: Because interesting, very energetic processes create this invisible radiation, and we can learn more about the Universe by studying it.
Note to Teacher: Illustrations of Astro-1 instruments can be found on page 41 of this guide. Paragraphs on the back of that page provide additional information.
Answers for Options for Extending the Lesson Across the Curriculum: Language Arts — Infra means below. Maybe it's called "below" red because it is a range of wavelengths whose frequencies are longer than red, and it is sometimes shown below red on the electromagnetic spectrum. Ultra means beyond. Ultra-modern is another word.
Art — **Note to Teacher:** See Student Activity, page 14.
Home Activities: Note to Teacher: See Student Activity, page 13.
Student Activity Answers: The Great Ice Race: 1. Ice cubes covered with darker cloths should melt more quickly. 2. Darker colors absorb heat; lighter ones reflect heat. 3. Dark colors should keep the wearer warm; light colors should help the wearer stay cool. 4. Space suits are white to reflect the Sun's heat.
Student Activity Answers: Pot-of-Gold Word Search: 1. Electromagnetic 2. Red, blue 3. Invisible 4. Filter 5. UV 6. Light, spectrum 7. Violet 8. Rainbow 9. Colors 10. Bulb 11. Bubble

Concept 2

Radiation exists above and below the visible portion of the electromagnetic spectrum.

Student Activity

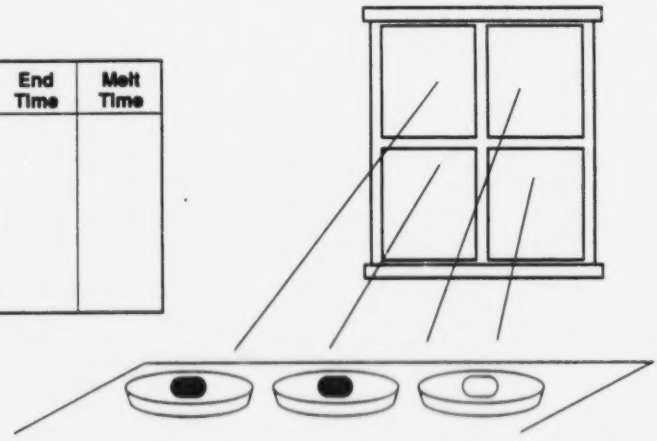
The Great Ice Race

Infrared radiation is heat. Certain colors absorb infrared radiation better than others. Try this experiment to see which colors absorb infrared radiation and which colors reflect it.

Materials Needed

- 3 or more ice cubes of about the same size
- the same number of flat dishes, all the same color
- pieces of cloth, each of a different color
- clock
- light source, preferably sunlight

Color	Start Time	End Time	Melt Time
1.			
2.			
3.			
4.			



Step 1: Put ice cubes in separate, flat dishes or containers in sunlight.

Step 2: Cover each cube completely with a different color cloth. Use a variety: ranging from very light to very dark.

Step 3: Write down starting time for experiment (start time).

Step 4: When ice cubes are completely gone, write down the time (end time).

Step 5: Subtract the start time from the end time to get the melt time.

Results

1. Which ice cube melted fastest?
2. Based on your results, which colors seem to absorb the most heat?
3. What colors should you wear when you want to stay warm? When you want to stay cool?
4. From what you have seen, can you guess why space suits are white?

Concept 2

Radiation exists above and below the visible portion of the electromagnetic spectrum.

Student Activity

A Black-and-White Vision

Try to imagine a world of black and white: no rainbows, charcoal-colored grass, pale-gray skies, black lakes and rivers, butterflies in shades of gray. A world like this sounds cold and unattractive to humans, but few people realize that the world appears just this way to many animals. Most mammals, except for apes and humans, have little color vision; some humans, too, are color-blind. Bees and butterflies, on the other hand, not only have color vision but can see into the ultraviolet region, and fruit flies can see almost up to the X-ray range. Fish, reptiles, and birds possess some color vision, but animals like dogs, cats, and horses see very little color at all. With this in mind, describe your room or your yard as your dog or cat might see it.

Concept 2

Radiation exists above and below the visible portion of the electromagnetic spectrum.

Student Activity

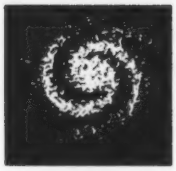
Pot-of-Gold Word Search

D P E O M R E Z B U L B M F S
A C S U A L V C A W T L U B P
F O W O N X I Y I K X U D E E
E L E C T R O M A G N E T I C
R O S E Q T L U V T L S L J T
A R A O B R E D U B R Y O U R
C S C N M F T W I Q U P A C U
R A R I D L G S X S O B J K M
G E G H R A I N B O W B B U E
P S P E F V G G I D I G M L N
Q V Q H N O I P H J H T U O E
F R F I L T E R L T K I A V Z

Fill in the blanks in the questions below by finding the correct words in the puzzle. The words run horizontally, vertically, and diagonally. Circle the words when you find them.

1. The whole range of energy waves from the longest to the shortest is called the _____ spectrum.
2. _____ , green, and _____ are primary colors of light.
3. X-rays are_____ to the human eye.
4. Looking at a red apple through a green _____ will cause it to appear black.
5. _____ stands for ultraviolet.
6. White _____ is broken into a _____ by a prism.
7. The color of visible light that is closest to the invisible higher frequencies is _____.
8. A _____ is produced when white light is refracted by raindrops.
9. There are seven _____ found in visible light.
10. An ordinary light _____ will not produce a complete spectrum when its light passes through a prism.
11. Interference color can be seen on the surface of a _____ .

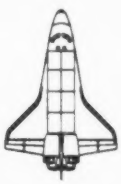
Seeing Waves Everywhere



Background

Try to visualize colors as having form and personality. Red waves are long and have little energy; green is a little shorter and more active; violet waves are short but energetic. Colors are found in visible light, and light is a kind of radiation. Radiation can be thought of as packets of energy called **photons** that travel in waves. Long waves travel with less **frequency** while short waves travel at the same speed but with greater frequencies.

Think about ocean waves. Light waves have high points, or **crests**, and low points, or **troughs**, just as ocean waves do. At the beach, do the gentle swells move your body? No, they just pick you up and set you down again. This is the nature of waves: energy traveling through things, rather than moving things.



Activity 1: Waves on a Rope

Wave action can be demonstrated easily with a piece of rope.

Materials Needed

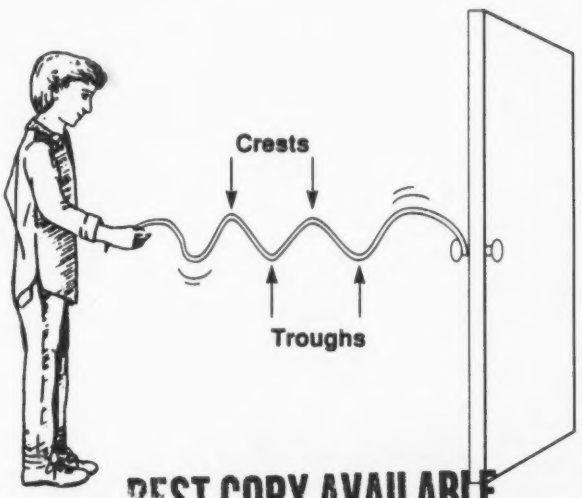
- piece of lightweight rope, approximately 4.5 ft (1.5 m) long

Step 1: Tie one end of the rope to a doorknob or desk and move the other end up and down.

Step 2: Move the rope up and down, slowly at first, and then with more energy.

Questions

1. What happens when the rope is moved slowly?
2. What happens when it is moved quickly?
3. What does this tell us about the energy of the source of the wave? Are long waves likely to be produced by a low-energy source or a high-energy source? What about short waves?
4. Exploding stars give off much energy. What kinds of waves would result?



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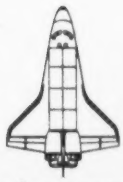


Activity 2: Waves in Water

Visible light is just a small part of the electromagnetic spectrum, the range of radiation from radio waves to gamma rays. These electromagnetic waves are usually identified by their frequencies because all waves travel at the same **speed** but have different wave frequencies. Radio waves travel at low frequencies; gamma rays, at the other end of the spectrum, travel at very high frequencies. To observe wave frequency, try this experiment. **Because this experiment involves water and electrical equipment, it should be done by the TEACHER ONLY.**

Materials Needed

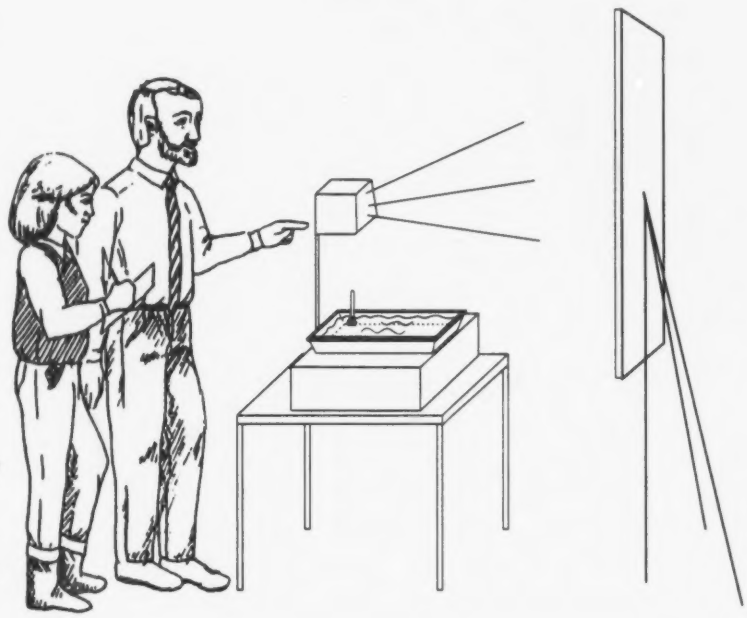
- clear glass pan, approximately 9 in. x 13 in., filled to a depth of about 1 in. (2 cm) with water
- tongue depressor
- putty or clay
- overhead projector

Step 1: Soften a piece of clay or putty and place it on the bottom of the pan near the end. Stand the tongue depressor with the clay.

Step 2: Fill the pan with water.

Step 3: Place the pan on the overhead projector surface.

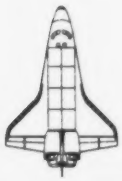
Step 4: Using the side of your hand, slowly strike the water's surface at the end opposite the stick. Waves will appear on the projector screen. Note how many waves pass the stick in 5 seconds. You may count by observing either wave crests or troughs passing the stick.



Step 5: Strike the water more quickly and again note the number of waves passing the stick in 5 seconds. You are seeing variations in wave **frequency.**

Questions

1. Which action produces more frequent waves?
2. Think about what you have observed. Can you write your own definition of frequency?



Activity 3: Looking at the Spectrum

It is important to study the different frequencies that make up the electromagnetic spectrum.

Materials Needed

- chart of the electromagnetic spectrum

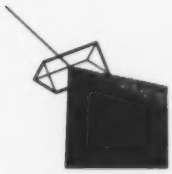
Look at the chart of the spectrum your teacher has given you or projected onto a screen or wall.

There are seven wavelength ranges. On this chart, the less energetic frequencies are on the left, the more energetic frequencies on the right. Those that were investigated in Concept 2 are beyond the visible spectrum. (The infrared and the ultraviolet.)

Astro-1 instruments are used in high-energy astronomy; they observe objects in the ultraviolet and X-ray ranges. These waves are shorter than visible light waves, but they are more energetic.

Questions

1. How do waves at the red end of the spectrum compare in length to the waves at the violet end?
2. Which waves probably are more energetic?



Options for Extending the Lesson Across the Curriculum

Language Arts

Did you know that you can speak Latin? In a dictionary that gives word origins, look up the prefix **astro**. What does it mean? Can you think of any other words that begin with this prefix? **Astro** is a Latin prefix. What does the fact that the Romans, who spoke Latin, had a word for "star" tell you about them? Their word for "sailor" was **nauta**. What word do **astro** and **nauta** make together?

Creative Writing

"Once upon a time, long, long ago, people could see ultraviolet radiation and X-rays . . . ." Write a legend that explains what happened to this imaginary ability.

Activity 1 Answers: 1. Long waves are produced. 2. Short waves are produced. 3. It tells us that the length of the wave is related to the energy of the source. Long waves are likely to be produced by a low-energy source. Short waves are likely to be produced by a high-energy source. 4. Short waves

Activity 2 Answers: 1. Striking the water quickly 2. Frequency is the number of crests or troughs passing a point in a unit of time. **Note to Teacher:** To do this as a student activity, suspend a clear light bulb over a glass pan set on a white surface. When other room lights are turned off, wave shadows can be seen clearly.

Activity 3 Answers: 1. Waves at the red end are longer than the waves at the violet end. 2. The waves at the violet end **Note to Teacher:** See page 47 for electromagnetic spectrum.

Answers for Options for Extending the Lesson Across the Curriculum: Astro comes from the Latin word **astra**, meaning "star." The fact that the Romans had a word for star tells us that they were interested in the stars. Roman sailors navigated by the stars, and **astronaut** means "star sailor."

Student Activity Answers: Metric Math Challenge — Making Long Numbers Short: 1. 6.5×10^{-7} m 2. 5.0×10^{-7} m 3. 2.2×10^{19} km 4. 4.0×10^{7} km 5. 1.0×10^{-5} or 10^{-5} cm

Student Activity Answers: The Spectrum and You: 1. Visible light 2. Ultraviolet rays 3. Radio waves 4. X-rays 5. Infrared 6. Microwaves

Student Activity Answers: The Long and Short of It: 1. Atom - X-ray waves 2. Statue of Liberty - radio waves 3. Dime - microwaves 4. Pinhead - infrared waves 5. Nucleus of an atom - gamma ray waves 6. White blood cells - ultraviolet light waves 7. Dust specks - visible light waves

Concept 3

Light and other kinds of radiation consist of photons that travel in waves.

Student Activity

Metric Math Challenge — Making Long Numbers Short

Now that you have a good idea of the sizes of wavelengths across the spectrum, let's work on writing the sizes as astronomers do. Scientists working with very large or very small numbers use a system called **scientific notation.** This shortens numbers by substituting powers of 10 for long strings of zeros. For example, the star nearest to us outside the solar system is Proxima Centauri, which is 4.3 light-years away. A **light-year,** the distance light can travel in a year, is almost 10 trillion kilometers, or 10,000,000,000,000 km. Proxima Centauri is 43,000,000,000,000 km away. Writing numbers this way would take a lot of time and paper, so instead astronomers move the decimal enough places to the left to leave the 4 by itself (4.3). Then, they multiply 10 by itself enough times to supply all the zeros: 10,000,000,000,000 or 10^{13}. Now, Proxima Centauri can be said to be 4.3×10^{13} km away.

Very small numbers can also be written this way. An X-ray is about 0.000000001 meter long. Now, however, the power of 10 is given as a negative exponent, 10^{-9}, and X-rays are said to be 1.0×10^{-9} m long or simply 10^{-9} m. More examples are given below. Can you figure out how to write these other wavelengths in scientific notation?

1. Red light is 0.00000065 m. Write in scientific notation. _____

2. Green light is 0.00000050 m. Write in scientific notation. _____

3. The nearest large galaxy, Andromeda, is 2.2 million light-years, or 22,000,000,000,000,000,000 km away. Write this in scientific notation. _____

4. Venus is 40,000,000 km from Earth. That is _____ km in scientific notation.

5. Written as _____ in scientific notation, a white blood cell is about 0.00001 cm long.

$10x10x10x10x10x10x10x10x10x10x10x10x10 = 10^{13}$ (10,000,000,000,000)

Number	Move Decimal	Powers of Ten	+/–	Scientific Notation
43,000,000,000,000.00	4.3 (13 places)	10x10x10x10x 10x10x10x10x 10x10x10x10x 10 = 10^{13}	+ >1	4.3×10^{13}
0.000000781	7.81 (7 places)	10x10x10x10x 10x10x10 = 10^{7}	– <1	7.81×10^{-7}

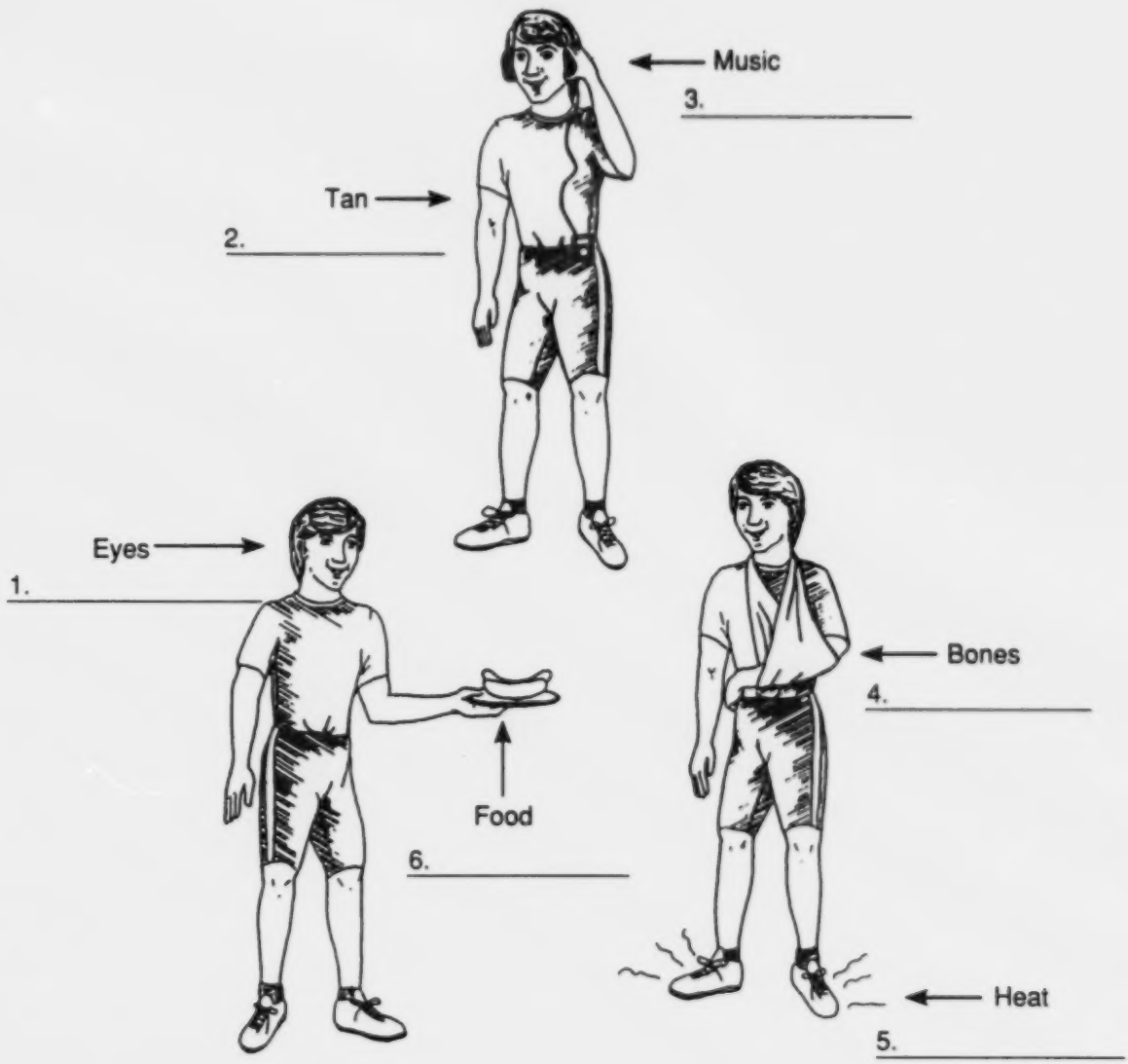
Concept 3

Light and other kinds of radiation consist of photons that travel in waves.

Student Activity

The Spectrum and You

Different radiation wavelengths are part of your everyday life. Write the name of the wavelength in the blank below the way that it affects your life.



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microwaves	radio waves
infrared	ultraviolet rays
visible light	X-rays

Concept 3

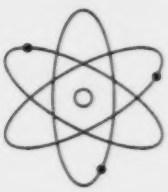
Light and other kinds of radiation consist of photons that travel in waves.

Student Activity

The Long and Short of It

Although the range of energy in the electromagnetic spectrum is continuous, it has been divided into seven categories of energy, distinguished by their wavelengths (the distance between their crests or troughs). Below are some objects approximately the same size as the wavelengths. Can you match the length of the wave with the size of the object? Write the name of the wavelength next to the object that is approximately the same size.

Objects



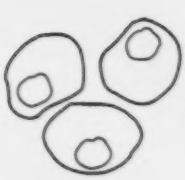
1. Atom _____

2. Statue of Liberty _____

3. Dime _____

4. Pinhead _____

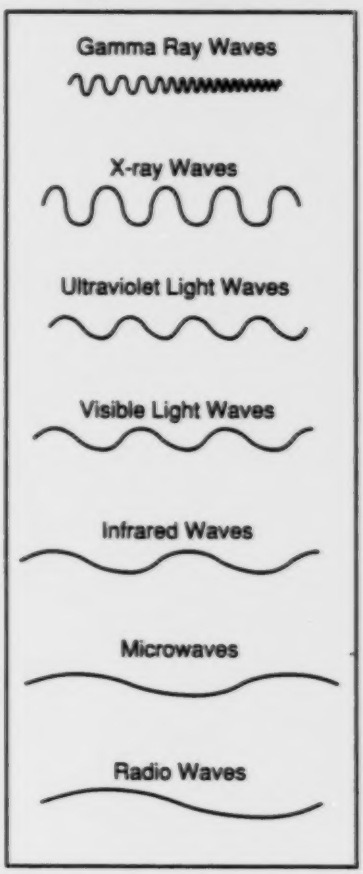
5. Nucleus of an Atom _____



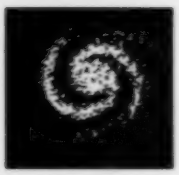
6. White Blood Cells _____

7. Dust Specks _____

Type of Radiation



Seeing Into the Universe



Background

Can you name the star nearest Earth? Did you remember that the Sun is a star? The Universe holds an incredible variety of objects. The twinkling stars and dusty Milky Way that we see in the night sky are only a small portion of what is actually there; many of the most fascinating objects in the Universe give off much of their energy as the invisible wavelengths that you have been studying: radio waves, infrared waves, ultraviolet rays, X-rays, and gamma rays.

Objects that give off a lot of energy emit short wavelengths, while objects that give off less energy emit longer wavelengths. Many of the objects we see by visible light, such as planets, are relatively cool; hotter objects, such as very new **stars** or old stars give off ultraviolet radiation. **White dwarfs**, which are small stars in the last stages of their lives, emit much of their energy as ultraviolet radiation and are sometimes in **binary star systems**, pairs of stars attracted to each other by gravity. In this star combination, the white dwarf may pull matter from a larger star, forming an **accretion disk,** the hot matter that connects the two stars.

Young **galaxies** give off large amounts of ultraviolet and X-ray radiation in their **spiral arms** where new stars are born and in their centers where high-energy processes take place. Galaxies come in several different shapes. Our galaxy, the Milky Way, is a spiral galaxy and has a pinwheel shape. Mysterious **black holes**, possibly the remains of collapsed giant stars, swallow even light. X-rays are given off as they consume everything close to them. **Neutron stars**, the tiniest and densest stars known, are also sources of X-ray radiation. Neutron stars may be found in the centers of **supernova remnants**, also called **nebulae**, the remains of giant exploded stars. The **interstellar medium**, the term given to the shapeless clouds of dust and gas between the stars, actually absorbs ultraviolet radiation and distorts astronomers' views.

These are just a few of the hundreds of kinds of intriguing objects in the Universe, but they are millions and millions of miles away, and we can learn about them only by studying the light messages they send through space. They exist in a Universe mostly hidden from the naked eye but visible to astronomers studying them with ultraviolet and X-ray instruments, such as those on Astro-1.

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Activity 1: Color and Temperature

Stars, like everything around us, come in different colors of visible light and also give off invisible radiation, such as radio waves, infrared waves, ultraviolet waves, X-rays, and gamma rays. You can see color differences with your naked eye. Cool, red stars can be picked out on a clear, dark night. How do astronomers know that red stars are cool?

Materials Needed

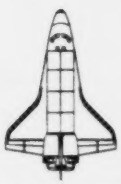
- wax candle
- matches

Step 1: Turn room lights down or off.

Step 2: Light the candle. Without getting too close, look carefully at the candle flame.

Questions

1. What colors do you see there?
2. Where are the different colors found? Describe their location in the flames.
3. Where would you guess that the hottest part of the flame would be?
4. What color would the hottest stars probably be?
5. The cooler stars?



Activity 2: How Far the Stars?

When you were growing up, you probably asked your parents lots of questions: Why is the sky blue? Why do dogs bark and cats meow? Why do stars twinkle? All of us are curious about the world around us. Astronomers try to answer questions about the Sun, the solar system, the Milky Way Galaxy, and the endless reaches of deep space. The incredible distances of the objects they study provide a real challenge.

To give you some idea of the distances, consider this: light travels about 186,000 mi (300,000 km) per second. It could travel the distance from New York City to Los Angeles in 1/100 of a second.

See if you can calculate the time it takes for light to travel to Earth from some of the objects closest to us. Remember, distance equals rate multiplied by time (D = RT), and light's rate of travel is 186,000 mi (300,000 km) per second.

Questions

1. The Moon is about 239,000 mi (384,000 km) from Earth. How long does it take sunlight reflected off the Moon to reach Earth?
2. The Sun is about 93,000,000 mi (150,000,000 km) away. When you are standing in the sunlight, how long did the light that falls on you have to travel?
3. The closest star to us, other than the Sun, is Proxima Centauri, which is about 26,000,000,000,000 mi (43,000,000,000,000 km) away. If your spaceship could travel at the speed of light, how long would the trip take?

Options for Extending the Lesson Across the Curriculum

Art
Use colored pencils or pastels to color the stars in the Hertzsprung-Russell Diagram of the main sequence, page 25. The colors should reflect the colors that are filled in at the bottom.

Creative Writing
Research black holes, then use your imagination to describe a trip into a black hole. How does it feel? How long does it take? What do you see? What is on the other side?

Music
Listen to "Thus Spake Zarathustra," the theme music from "2001: A Space Odyssey." Why do you think it was selected for this movie? Another selection is "Neptune" from Holsts' "Planets." What imagery does it convey?

Home Activities

Look at a 3-D book with special glasses, then without. Describe the differences between the two images that your special glasses make. Do these special glasses make it possible to see more clearly and completely? Is this similar to the way astronomers use special instruments to observe celestial objects?

If you have access to a VCR, rent a "space movie" such as "2001: A Space Odyssey," "Star Wars," or others. What kinds of music were used? Was the story based on any scientific principles?

Activity 1 Answers: 1. White, blue, orange, and red 2. The center of the flame is white, with blue at the top. Outer parts are reddish-orange. 3. The hottest part, which is blue, is just above the center. 4. The hottest stars would be blue. 5. Cooler stars are reddish-orange.
Activity 2 Answers: 1. 1.28 seconds 2. Approximately 8 minutes 3. About 4.3 years
Student Activity Answers: The Hertzsprung-Russell Diagram: Temperatures (left to right): 20,500°; 10,000°; 7,000°; 5,500°; 5,000°; 3,500°. Colors (left to right): violet, indigo, blue, white, yellow, orange, red. 1. Mass increases also. 2. Blue 3. Red 4. White
Student Activity Answers: Scrambled Eggs-tra Galactics: Note to teacher: It may be necessary to discuss the shapes and processes of these objects before assigning this activity to students. See Concept 4, Background, page 22.
1. Black hole 2. Supernova remnant 3. Neutron star 4. Galaxy 5. Spiral arm 6. Binary star system 7. White dwarf 8. Accretion disk 9. Interstellar medium 10. Star

Concept 4

Certain celestial objects give off radiation other than visible light, and we must study them in other energy ranges.

Student Activity

The Hertzsprung-Russell Diagram

Astronomers need to study all ages and types of stars. This is what the Astro-1 mission will do. Astro-1 telescopes will observe young stars, middle-aged stars like our Sun, and older stars near their death.

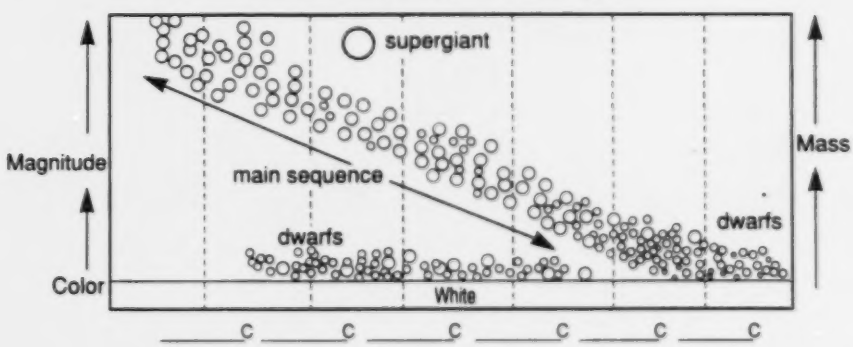
Two astronomers, Ejnar Hertzsprung and Henry Russell, studied the lives of stars in the early part of this century. Though they did not work together, both found that there is a relationship between the brightness, or **magnitude**, of a star and its temperature: as the temperature increases, the brightness increases, unless the star appears bright just because it is close. This relationship forms a pattern, shown on the **Hertzsprung-Russell (H-R) Diagram**. This pattern runs from the upper left to the lower right of the diagram. The stars in this area are called **main sequence stars**.

Later, scientists discovered that there is a relationship between a star's temperature and mass. Mass is the amount of matter in an object. Stars with more mass burn differently and have higher temperatures than stars with less mass. This is shown on the H-R Diagram. The diagram also reveals the relationship between star temperature and color: hotter, more massive stars are blue, while cooler, less massive stars are red.

Step 1: Fill in the temperatures in the spaces at the bottom of the chart. Remember that the stars in the upper left corner are the hottest. Where will the highest temperature go?

Step 2: Some of the colors are missing from the chart. Use what you have learned about star colors (colors in the shorter frequencies, like ultraviolet, are from hotter objects) to fill in the missing colors. Read carefully.

The Hertzsprung-Russell Diagram



Temperatures
5,000°, 7,000°, 3,500°, 20,500°, 5,500°, 10,000°

Colors
red, indigo, yellow, violet, orange, blue

Questions

1. As magnitude increases, what happens to mass?
2. What color will the supergiant in the upper left be?
3. What color will the dwarfs in the lower right be?
4. What color will the dwarfs in the center be?

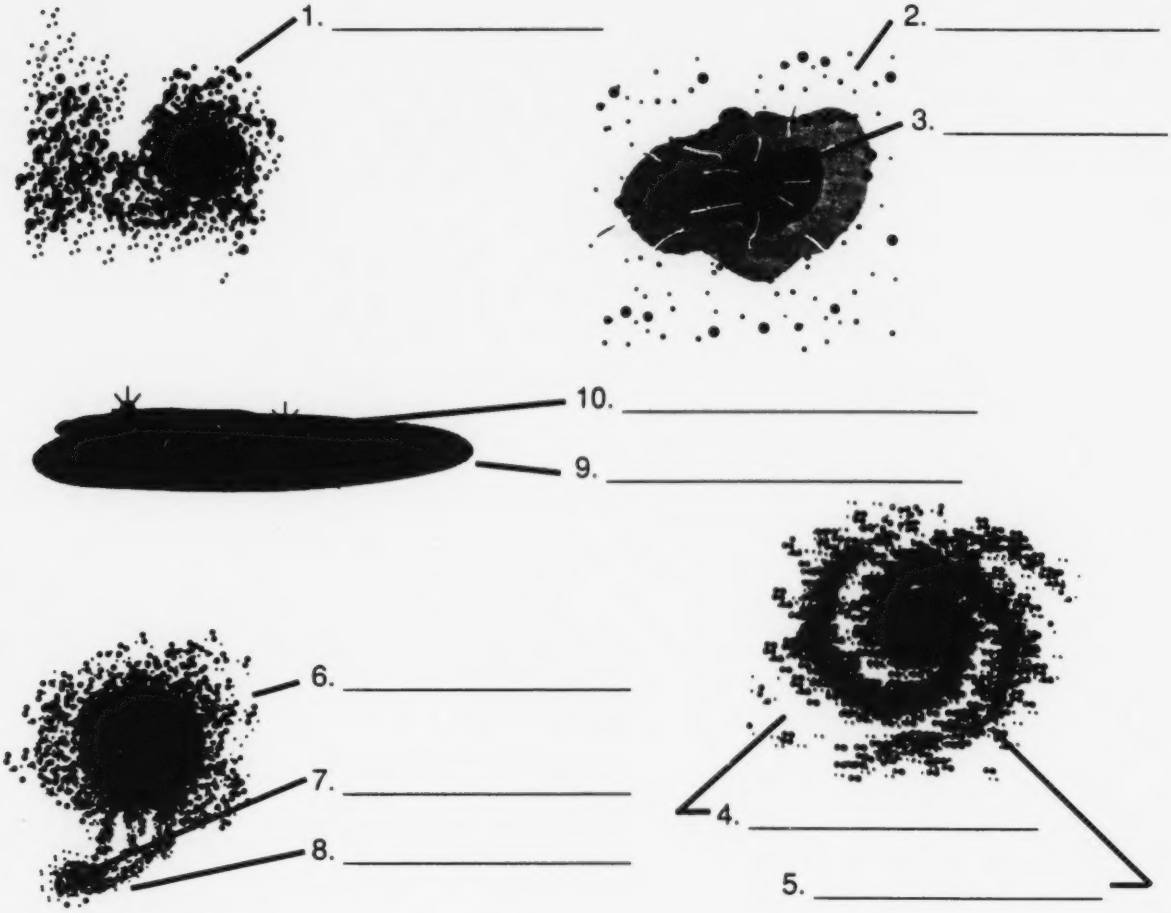
Concept 4

Certain celestial objects give off radiation other than visible light, and we must study them in other energy ranges.

Student Activity

Scrambled Eggs-tra Galactics

Shown below are some of the objects that will be observed by the Astro-1 telescopes. Astronomers have never seen black holes; this drawing just suggests what they may be like. Unscramble the names below. Then match them with the objects or parts of objects by writing the names on the blank next to the object.



lcakb ohel _____

aibrny srta tyssme _____

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rats _____

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psroavneu rtnneam _____

tnuroen rats _____

leitsalerrtn uidmme _____

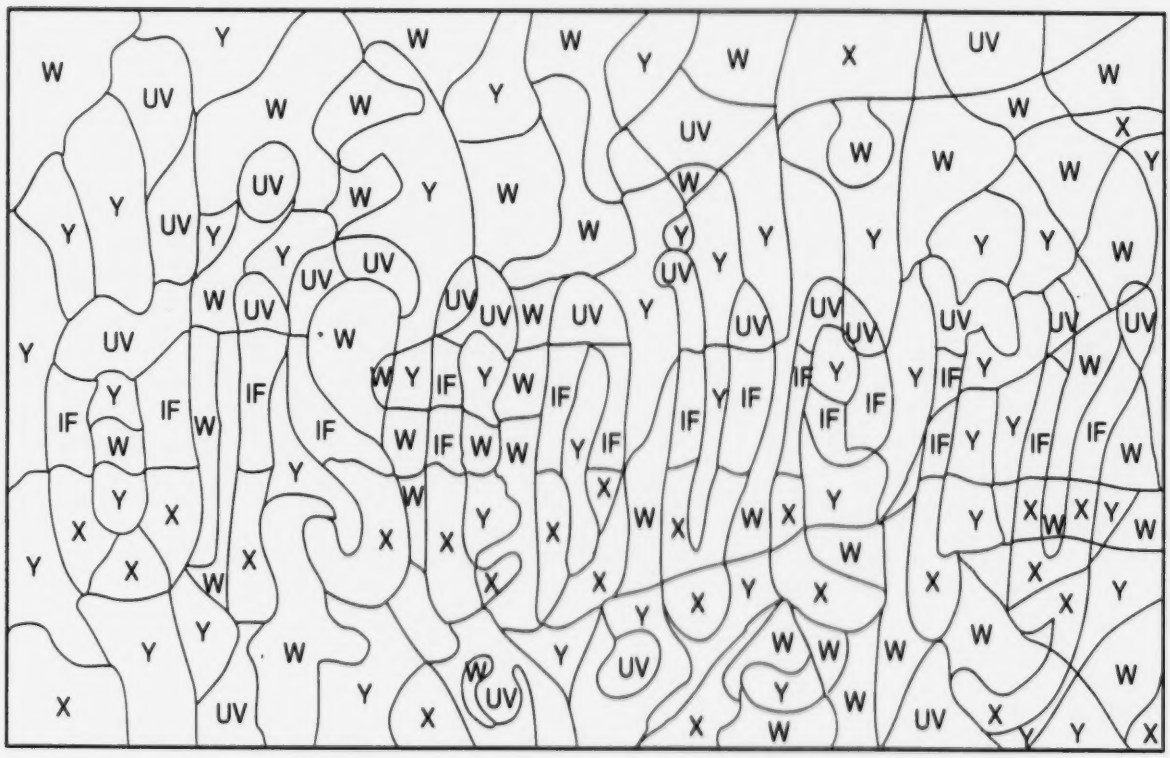
Concept 4

Certain celestial objects give off radiation other than visible light, and we must study them in other energy ranges.

Student Activity

Getting the Whole Picture

If we could view the Universe in only one wavelength, we would miss some very important things. Wavelengths other than visible light are needed to see certain objects in space: ultraviolet (UV), infrared (IF), and X-rays (X). Use colored pencils to fill in the coded blanks. First, color the UV pieces purple. Can you see what it is? Leave W white, but color Y pieces light yellow. Color IF blanks red. Now can you tell? Make the X pieces black. Now you're seeing in several wavelengths. What could you have missed?


W Y W W Y W X UV W
UV W W Y UV W X
UV W Y W W W Y
Y Y UV Y W Y Y Y Y W
UV Y UV UV Y UV
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W Y W X
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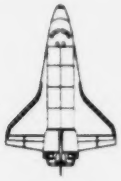
X W UV X Y X

Seeing Through a Filter

Background

Think of Earth's atmosphere as a pair sunglasses — a barrier that repels some forms of radiation while allowing others through. Sunglasses allow visible light to pass through but block certain other rays. Like sunglasses, the atmosphere absorbs or scatters certain waves of radiation coming from the Sun, stars, and other objects in space. Most ultraviolet waves, X-rays, and short, highly energetic **gamma rays** from space do not reach Earth's surface nor do some wavelengths in the longer infrared and **microwave** ranges. The atmosphere protects animal and plant life from harmful radiation that can cause skin cancer in humans and affect plant photosynthesis. At the same time, the atmosphere blocks the infrared, ultraviolet, X-ray, and gamma-ray radiation that allow us to "see" objects in the Universe in other energy ranges.



Activity 1: Refraction

Use a jar of cloudy water and a flashlight to demonstrate refraction. The bending of the light wave demonstrates one of the ways that the atmosphere affects light waves.

Materials Needed

- 1-qt (1- ℓ) jar (clear glass)
- small flashlight with narrow beam
- water
- few drops of milk

Step 1: Fill the jar with water. Add a few drops of milk to make the water cloudy.

Step 2: Shine the flashlight into the water below the surface.

Step 3: Move the flashlight up to the water's surface.

Questions

1. What happens when the light beam shines through the water below the surface?
2. When the light beam travels from air into water, what happens?
3. If Earth's atmosphere contains particles of dust and water vapor, what do you think happens to radiation coming into the atmosphere?

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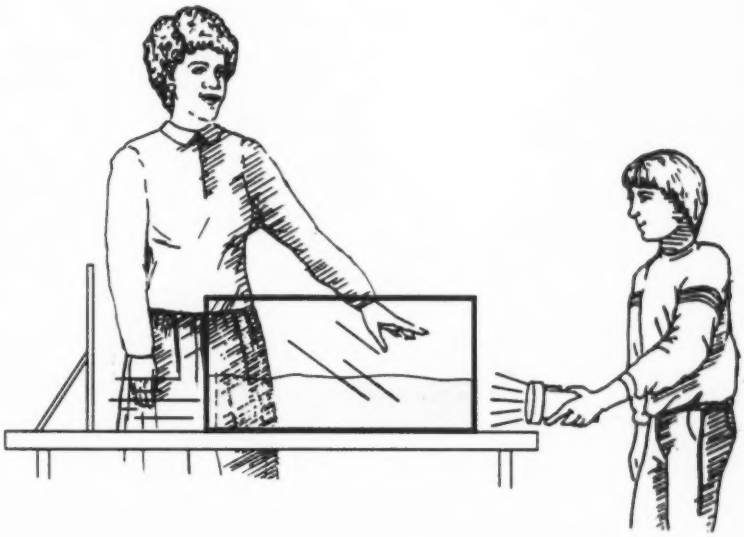
Activity 2: The Atmosphere and Color

To show the effect of the atmosphere on the Sun's rays, try this experiment. Use only diluted acid. **This should be done by the TEACHER ONLY, even though the acid listed is very diluted.** The aquarium may be used for other purposes if washed thoroughly after this experiment.

Materials Needed

- 5-gal (20- ℓ) rectangular aquarium (clear glass)
- 1 gal (4 ℓ) water
- 10 g sodium thiosulfate or sodium hyposulfite (photographic fix)
- 160 ml 0.5N solution of sulfuric acid
- flashlight
- white screen



Step 1: Mix thiosulfate and water (this amount is not critical) in the aquarium.

Step 2: Add 160 ml of diluted sulfuric acid and stir with glass rod.

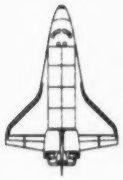
Step 3: Project light through aquarium to screen.

Questions

1. At the beginning, what color is the water when the flashlight shines through it?
2. What color is the light of the flashlight when viewed directly?
3. How does the color of the water change as time goes on?
4. What causes the water to change color?
5. What is the final color of the light?
6. Why? Have you seen anything like this in nature?

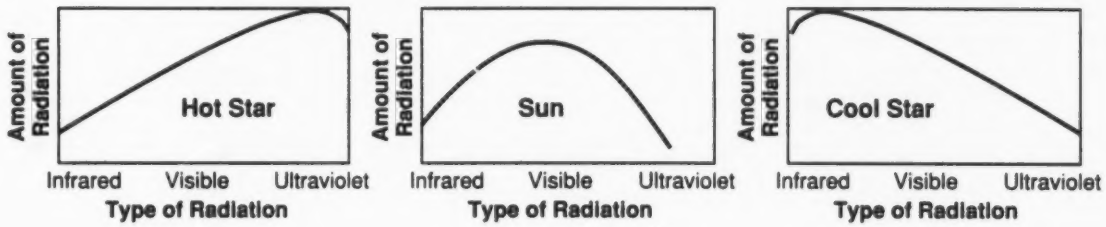
More Help

This demonstration helps explain the scattering effects of Earth's atmosphere on different wavelengths. Think of the water in the aquarium as Earth's atmosphere and the flashlight as the Sun. The reaction of the acid on the sodium thiosulfate creates very fine particles, and very fine particles in the atmosphere cause the sunlight to scatter. The scattering effect first removes the violet and blue end of the spectrum (the shorter waves) and later the red end (the longer waves) as the particles grow larger. Short waves are scattered more than long waves and are scattered by smaller particles than are long waves.



Activity 3: A Picture of a Different Color

Most high-energy radiation, such as ultraviolet, X-ray, and gamma-ray emissions, does not penetrate Earth's atmosphere. Many objects in space, however, give off much of their energy in these ranges. Therefore, scientists must go above the atmosphere to study these objects. Look at these diagrams of star energies.



Questions

1. Hot stars emit most of their radiation in what range?
2. Cool stars emit most of their radiation in what range?
3. Would any of these three stars be invisible to a traveler passing in a spaceship?
4. Would it be correct to say that Earthbound astronomers are, in a way, "color-blind" because their instruments cannot detect all the wavelengths?

Options for Extending the Lesson Across the Curriculum

Creative Writing

Ultraviolet rays cause suntans. If we are not careful, they can also cause sunburns. Use your imagination to write a description of what X-rays would do if not blocked by the atmosphere. What effect would X-rays have on plants? Animals? Use lots of descriptive words.

Home Activities

Observe sky color differences at sunrise, noon, and sunset. How is this like the classroom experiment?

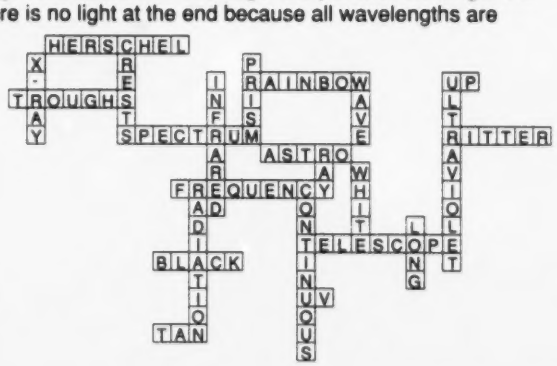
Activity 1 Answers: 1. The beam appears to widen slightly but doesn't bend. 2. The beam bends when it hits the water. 3. Radiation entering Earth's atmosphere is absorbed, reflected, or transmitted.

Activity 2 Answers: 1. A blue-violet color 2. White 3. Goes from blue to yellow-green, to orange, and then red 4. The size of the particles increases, and so different wavelengths of light are scattered. The larger the particle, the longer the wavelength that is scattered. 5. No light comes through. 6. There is no light at the end because all wavelengths are being scattered. A similar situation occurs at sunset.

Activity 3 Answers: 1. Ultraviolet 2. Infrared 3. No. All three give off at least some of their radiation in the form of visible light. 4. Yes. Astronomers could be considered color-blind because they must look through the filters of Earth's atmosphere.

Student Activity Answers: Surfing on Math Waves:
(a) 50 (b) 4 (c) 50 (d) 0.4 (e) 0.15 (f) 0.6

Student Activity Answers: Crosswords and Colors:



Student Activity Answers: Atmospheric Sunglasses:
1. Radio waves 2. Microwaves 3. Infrared waves 4. Visible light (given) 5. Ultraviolet waves 6. X-rays 7. Gamma rays

Concept 5

Certain waves of radiation are blocked by Earth's atmosphere.

Student Activity

Surfing on Math Waves

You have learned that waves have **lengths**, which is the distance between two neighboring **crests** (high parts) or between neighboring **troughs** (low parts). They also have **frequencies.** The frequency of a water wave, for instance, can be described as the number of crests of a water wave passing a particular point in 1 second. The number of complete waves passing during 1 second is the frequency (f) of that wave. Frequency is measured in **Hertz (Hz)**, named after Heinrich Hertz, who was one of the first to study light waves. One complete wave passing a point each second is a frequency of 1 Hz.

Photons, the packets of energy that make up light and other forms of radiation, also have **velocity.** In space, all energy waves travel at the same velocity.

The relationship between wavelength, velocity, and frequency of waves is expressed this way:

$$\text{wavelength} = \frac{\text{velocity}}{\text{frequency}} \qquad w = \frac{v}{f}$$

You can use different forms of the same expression to find velocity and frequency:

$$\text{frequency} = \frac{\text{velocity}}{\text{wavelength}} \qquad f = \frac{v}{w}$$

and

$$\text{velocity} = \text{frequency} \times \text{wavelength} \qquad v = f \times w$$

Below is a chart with velocity, frequency, and wavelength. Use the equations given above to figure out the missing figures. Happy surfing.

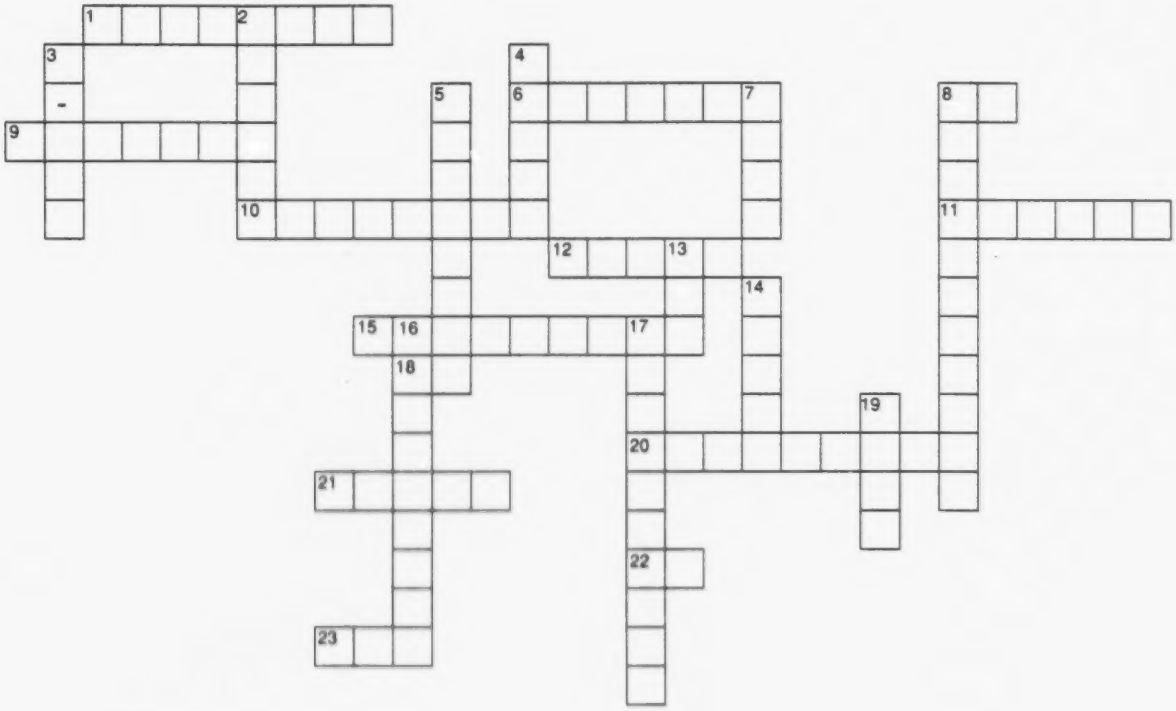
Wavelength (meters)	Frequency (Hertz)	Velocity (meters per second)
(a)_____	3	150
(b)_____	2	8
0.5	(c)_____	25
4.0	(d)_____	1.6
0.5	0.3	(e)_____
0.4	1.5	(f)_____

Concept 5

Certain waves of radiation are blocked by Earth's atmosphere.

Student Activity

Crosswords and Colors



Across

1. The man who proved the existence of infrared radiation.
6. Produced when sunlight hits raindrops.
8. The opposite of down.
9. The low parts of waves.
10. Continuous range of energy.
11. The man who discovered ultraviolet rays.
12. One Space Shuttle program that will put telescopes in space.
15. How often a complete wave occurs.
18. The ancient Greeks studied the stars B.C. We study the stars ____.____.
20. Instrument that can be used to view distant objects.
21. The color of paint that absorbs all colors.
22. Abbreviation for ultraviolet.
23. What ultraviolet rays can do to your skin.

Down

2. The tops of waves.
3. The kind of radiation that reveals broken bones.
4. Transparent object with triangular sides that can be used to produce a spectrum.
5. The kind of radiation that warms us.
7. Shape of radiation paths. Has crests and troughs.
8. The frequency above violet.
13. A narrow beam of radiation (X-_____).
14. The color of light that can be spread out into a spectrum with a prism.
16. Another name for energy.
17. Unending.
19. In terms of length, gamma ray waves are short; infrared waves are _____.

Concept 5

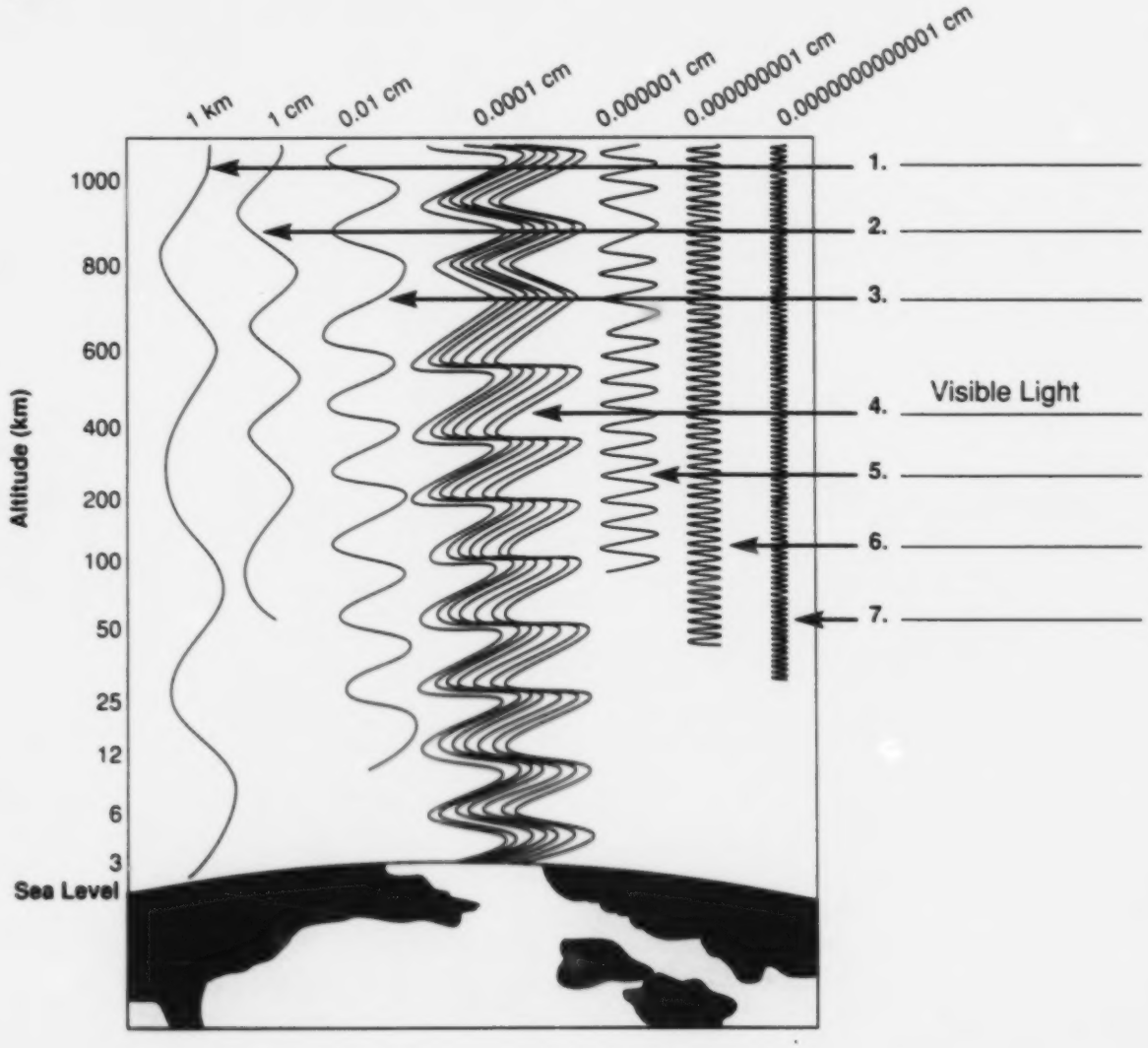
Certain waves of radiation are blocked by Earth's atmosphere.

Student Activity

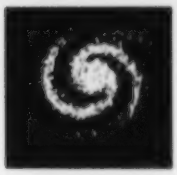
Atmospheric Sunglasses

This chart will give you an idea of how Earth's atmosphere, its "sunglasses," works to filter harmful wavelengths, such as X-rays and gamma rays, while admitting visible light. The altitude is given on the left, and the approximate length of the wave in centimeters is given at the top.

Write in the names of the wavelengths at the correct places. Remember that the shorter, more energetic wavelengths are absorbed by the atmosphere. Visible light is shown for you.



Seeing Above the Atmosphere



Background

The study of the skies is an ancient one: the earliest farmers sowed and reaped crops according to the phases of the Moon; sailors and explorers steered their courses by the stars; many, like the wizards of the Middle Ages, have tried to understand the present and foretell the future by studying the stars.

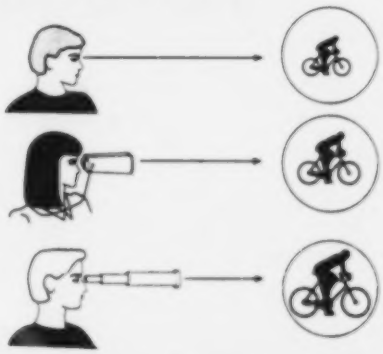
Have you ever looked through a **telescope**? Simple telescopes, made of lenses, mirrors, and a tube, have been used to examine distant objects for hundreds of years. More recently, larger and more complex telescopes have evolved but have been Earthbound. With the coming of the space age, astronomers have been able to place instruments above the dust and glare of the atmosphere to study the size, shape, and structure of the stars, galaxies, and other objects.

Activity 1: Seeing Farther

Astronomers use large telescopes to collect as much light as possible from celestial objects. By examining that light, they can determine what elements, such as iron or calcium, are in the object. They can also learn much about the object's shape. Try this experiment with some simple instruments. Note: Some telescopes can give an inverted image. Does yours?

Materials Needed

- binoculars
- telescope



Step 1: Go outside or look through the window at some distant object. How big does the object look?

Step 2: Look at the same object with a pair of binoculars. Now, how big does the object look?

Step 3: Look at the same object with a simple **telescope**. How big does it look now? For years, telescopes like this one, which collects visible light, were the main sources of information about the stars. Many stars and other objects give off radiation in forms other than visible light, but the atmosphere blocks most of the higher energy waves. Astronomers have been sending satellites with telescopes above the atmosphere for many years. Now, they are sending Astro-1 on the Space Shuttle with four telescopes that detect ultraviolet waves and X-rays.

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Activity 2: The Astro-1 Telescopes

Materials Needed
- illustrations of Astro-1 instruments

Look at the illustrations of the Astro-1 instruments your teacher has given you or projected onto the wall.

The **Hopkins Ultraviolet Telescope (HUT)** will use an instrument called a spectrograph to study the spectra of galaxies and other objects. Astronomers can determine what elements a particular object contains because each element creates a definite pattern in the spectrum. For example, hydrogen has a unique signature that always appears in certain places on the spectrum. The **Ultraviolet Imaging Telescope (UIT)** will take ultraviolet pictures of hot stars and other objects to reveal their structure and brightness. The **Wisconsin Photo-Polarimeter Experiment (WUPPE)** [pronounced "whoopee"] will examine the shape of stars and the dust that floats in space by seeing how these objects polarize, or direct, light. The **Broad Band X-Ray Telescope (BBXRT)** will study X-rays from different sources in the Universe, including quasars, the most distant objects in the Universe.

Questions
1. What two energy ranges do these instruments explore?
2. From what you know about Earth's atmosphere, why do you think it is important to take these telescopes and other instruments into space?

Activity 3: Polarization

One of the Astro-1 telescopes, the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), uses special instruments to study light from celestial objects. Try this experiment to examine the direction of light waves.

Materials Needed
- polarized filter or
- polarized sunglasses
- light source, preferably sunlight
- shiny, horizontal surface, such as a mirror

Step 1: Put the sunglasses on.

Step 2: Look through the lenses at the shiny surface.

Step 3: With the sunglasses still in place, tilt your head to the right or left about 90°.

Questions
1. A horizontal surface reflects **horizontal** light waves. Which way did the sunglasses block more light?
2. Polarized sunglasses are made from a material that blocks light waves coming from certain directions but not from others. Which way do you think the blocked light waves are moving — vertically or horizontally?
3. If **photo** means "light," and **polar** refers to "direction," what do you think a photo-polarimeter experiment will measure?

Options for Extending the Lesson Across the Curriculum

History

Research Ptolemy's concept of the solar system (Earth-centered, or geocentric) and Copernicus' concept of the solar system (Sun-centered, or heliocentric) and report to the class on what you find.

Art

Look up Ptolemy's Earth-centered concept of the solar system and Copernicus' concept of the solar system. Draw these same concepts for the class.

Literature

You may want to read E.A. Robinson's poem, "Merlin," or T.H. White's *The Book of Merlin*, which is the final chapter of *The Once and Future King*. You also may enjoy listening to "Camelot," which is the musical version of White's book. All of these deal with King Arthur and the Knights of the Round Table and contain references to an early wizard — Merlin.

Archaeology

If you are interested in archaeology or early astronomy, you may want to research Stonehenge in England. From your research, write a report, draw a picture and present an oral report, or build a model of Stonehenge. If you would like to work in a small group, get several classmates to work with you on this.

Home Activities

Watch for newspaper articles about the Astro-1 mission, scheduled to fly in the spring of 1990. Bring these to class and share them. Also be sure to watch for information about Astro-1 on TV.

Activity 2 Answers: Note to Teacher: Illustrations of Astro-1 instruments are found on page 41.
1. Ultraviolet and X-ray 2. These instruments will have to be above the scattering and absorbing effects of Earth's atmosphere to collect ultraviolet and X-ray radiation from celestial objects.
Activity 3 Answers: 1. They block more light in normal wearing position. 2. The blocked light waves are those moving from side-to-side (horizontally). Those that move through the sunglasses are moving up and down (vertically) 3. It will measure the direction of light from an object.
Options for Extending the Lesson Across the Curriculum: Note to the Teacher: See Study Print of Stonehenge, page 43.
Student Activity Answer: Room With A View: Note to Teacher: See Study Print of Whipple Observatory Telescope, page 45. 3. Early rockets - 100 km; later rockets - 200 km; Space Shuttle - 350 km; scientific satellites - 1,000 km
Student Activity Answer: SNAC (Students Need Acronyms for Comprehension): 1. ultraviolet 2. rest in peace 3. National Football League 4. North Atlantic Treaty Organization 5. Federal Bureau of Investigation 6. radio detecting and ranging 7. General Motors 8. Volkswagen 9. National Association for the Advancement of Colored People 10. sound navigation ranging 11. Internal Revenue Service 12. University of California at Los Angeles 13. Wisconsin Ultraviolet Photo-Polarimeter Experiment 14. personal computer 15. Broad Band X-Ray Telescope 16. Massachusetts Institute of Technology 17. United Nations 18. Bavarian Motor Works 19. American Federation of Labor - Congress of Industrial Organizations 20. Atlantic & Pacific (Tea Company) 21. intelligence quotient 22. Union of Soviet Socialist Republics 23. General Electric 24. Students Against Drunk Driving 25. American Telephone and Telegraph 26. National Aeronautics and Space Administration 27. light amplification by stimulated emission of radiation 28. American Football League 29. Young Urban Professional 30. Ultraviolet Imaging Telescope

Concept 6

Astronomers need to place telescopes above Earth's atmosphere to perform astronomical observations in several regions of the spectrum.

Student Activity

Room With A View

If you wanted a good view of the Moon and stars, where would you put your telescope? At the top of a building or on your front porch? In a city or in the country? Where would you be able to see the stars best?

Since Galileo first turned a telescope to the stars, astronomers have been trying to see farther and more clearly. It was not until 200 years after the first telescope was invented, however, that it occurred to astronomers to put telescopes on the tops of mountains. There, higher in the atmosphere and above the dust and lights of the cities, the view was better.

The first mountaintop observatory was the Lick Observatory, built in California in 1887. It held a **refractor** telescope with a 36-in. (91-cm) lens. As time went on, astronomers built bigger and bigger telescopes. Larger telescopes collect more light and enable astronomers to see fainter and more distant objects. In 1904, a large **reflector** telescope with a 4.9-ft (1.5-m) mirror was built on Mt. Wilson, and in the 1940s, an even bigger reflector telescope with a 16.6-ft (5.08-m) mirror was built on Mt. Palomar.

After World War II, scientists began to use captured German rockets to explore up to 62 mi (100 km) above the Earth; later rockets soared up to 124 mi (200 km) to take pictures of astronomical objects from above the atmosphere. The Space Shuttle will carry the Astro-1 telescopes about 218 mi (352 km) above Earth. Scientific satellites can travel 621 mi (1,000 km) above Earth or even higher. For a better understanding of astronomy on Earth and above, try these activities:

1. Research **refractor** telescopes. Describe these briefly and sketch one on the back of this sheet. Be sure to show light paths and label the parts.

2. Read about **reflector** telescopes. Describe these briefly and sketch one on the back of this sheet.

3. Write in the name of the following instruments next to the appropriate altitude shown on the Atmospheric Sunglasses Chart, Concept 5, page 33: early rockets, later rockets, Space Shuttle, scientific satellites.

Concept 6

Astronomers need to place telescopes above Earth's atmosphere to perform astronomical observations in several regions of the spectrum.

Student Activity

Who Invented It?

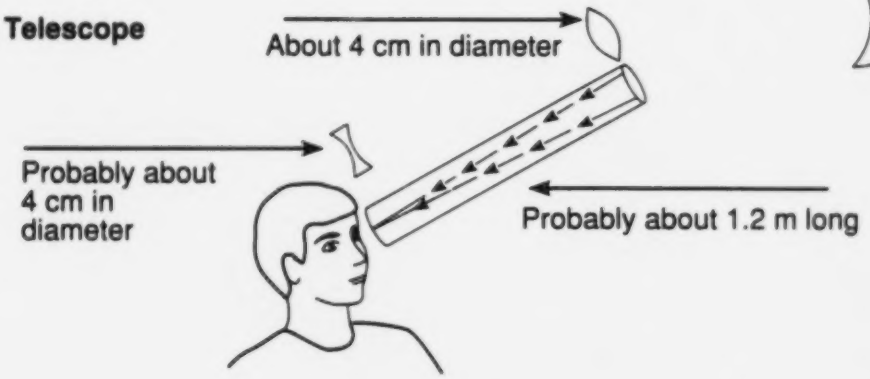
You have probably heard that Galileo invented the telescope. Actually, he probably did not invent it but was the first person to use the telescope to observe planets and stars. It is possible that the person who invented the telescope was Hans Lippershey (lip'-per-shee) who lived in Holland about 1600. The story is that two children were in Lippershey's spectacle (eyeglasses) shop, playing with the lenses. They put two lenses together and then looked through both at the same time at a distant weather vane on top of the town church's steeple. It was magnified. Lippershey looked through the children's invention and began making telescopes himself. After that, many people tried to claim that they had invented the telescope. Galileo himself wrote, "The first inventor of the telescope was a simple spectacle-maker," and did not claim credit for the discovery.

Below is a drawing of what early telescopes probably looked like. Label the **eyepiece** (the **concave** lens), the **objective** (the **convex** lens), and the **tube**. Look up **concave** and **convex** to do this activity.

Concave means _____

Convex means _____

An Early Telescope



The lines in the telescope trace the path of the light in this **refracting** telescope. In a few sentences, describe the light's journey from the Moon to the eye.

_____

_____

_____

_____

Concept 6

Astronomers need to place telescopes above Earth's atmosphere to perform astronomical observations in several regions of the spectrum.

Student Activity

SNAC (Students Need Acronyms for Comprehension)

An acronym is a word or word-like group of letters made from letters of a phrase. HUT, for example, comes from the name Hopkins Ultraviolet Telescope, one of the instruments aboard the Astro-1 mission.

Below are some other acronyms. Some are from the space program, while others are from government, sports, business, and science.

See how many you can identify. Many can be found in the dictionary. Good Luck.

1. UV _____
2. RIP _____
3. NFL _____
4. NATO _____
5. FBI _____
6. radar _____
7. GM _____
8. VW _____
9. NAACP _____
10. sonar _____
11. IRS _____
12. UCLA _____
13. WUPPE _____
14. PC _____
15. BBXRT _____
16. MIT _____
17. UN _____
18. BMW _____
19. AFL-CIO _____
20. A & P _____
21. IQ _____
22. USSR _____
23. GE _____
24. SADD _____
25. AT&T _____
26. NASA _____
27. laser _____
28. AFL _____
29. yuppie _____
30. UIT _____

Your Career in Astronomy

It was early in the morning on a cold mountaintop in Chile. Twenty-nine-year-old Ian Shelton was developing pictures taken through his simple, 10-in. refractor telescope. The pictures were of the Large Magellanic Cloud, or LMC, the nearest galaxy to our own, just 170,000 light-years away. As he developed the photographic plates, he suddenly noticed something strange: a bright star near the center, one that was not there 2 days earlier. Shelton walked outside to look for himself, and sure enough, there was a something new in the sky. Shelton had become the first person to photograph the supernova, the huge, violent explosion marking the death of a star. This star explosion was named Supernova 1987A, the first of 1987, but also the first in 383 years near enough to be seen with the naked eye.

Few astronomers are lucky enough to be the first to see a supernova, but all of them study fascinating objects: clusters of millions of stars, mysterious black holes, tiny, dense neutron stars, and vast, brilliant galaxies. Astronomers study these using a variety of Earthbound instruments: telescopes that detect visible light, radio, infrared, and ultraviolet radiation. They use spectrometers to study the chemistry of celestial objects and polarimeters to study their geometry. Many astronomers now make observations with instruments aboard satellites. Some astronomers, like those crew members flying on Astro-1, will even go into space themselves to study these distant objects in different ranges of the spectrum. Over the next 10 years, NASA will send several new telescopes, such as the Hubble Space Telescope, the Gamma-Ray Observatory, the Advanced X-Ray Astrophysics Facility, and the Space Infrared Telescope Facility into orbit. These huge instruments will open incredible new vistas for astronomers.

What kind of person becomes an astronomer?

Are you curious? Do you wonder how things work or what they are made of? Are you interested in where things come from and how they began? Do you work well both alone and in groups? Do you enjoy math? Are you willing to work at something that is interesting to you? Astronomers often have these qualities.

What do astronomers do?

Many astronomers teach and do research in colleges and universities, like the astronomers who developed the Astro-1 instruments; some astronomers teach in high schools. Others work in observatories, museum planetariums, and government and private research organizations.

How can you become an astronomer?

Middle School

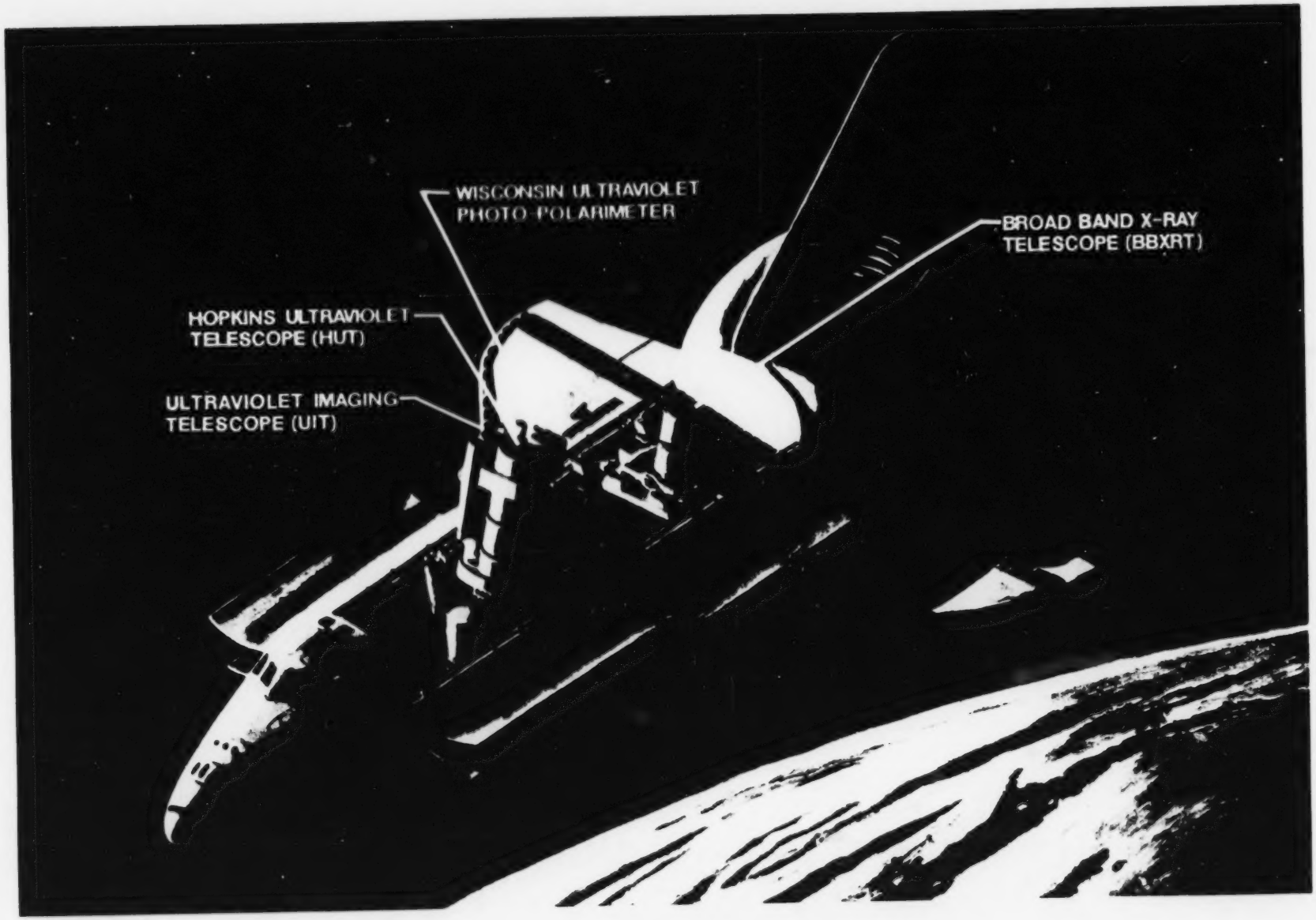
Middle school students should study mathematics and science and work on developing good communication skills, which astronomers need in order to share information and discoveries. You can also do things outside school: build a telescope, join or start an astronomy club, and visit a planetarium or observatory near you.

High School

You will need to take more mathematics and plenty of science courses such as physics, chemistry, and Earth science. Continue your studies in the language arts as well. Computer courses at both the middle school and high school levels are very helpful.

College

You would work for a bachelor's degree in astronomy, mathematics, or physics and probably go to graduate school.



41 **Astro-1**

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Astro-1 Facts

To see ultraviolet radiation and X-rays from astronomical objects, telescopes must be placed above the lower atmosphere, which absorbs most types of radiation before they reach telescopes on Earth.

Astro-1 is the first Shuttle mission dedicated completely to astrophysics, the branch of astronomy that investigates the physical characteristics of celestial objects, such as their size, mass, temperature, and chemistry. Three ultraviolet telescopes and one X-ray telescope will observe a variety of celestial objects. The observations will emphasize hot and energetic sources, some of the most dynamic objects in the Universe.

The Astro-1 Instruments

Hopkins Ultraviolet Telescope (HUT)
The Johns Hopkins University, Baltimore, MD; Principal Investigator: Arthur F. Davidsen
The telescope probes the most energetic part of the ultraviolet spectrum, an almost unexplored region that holds secrets about the chemistry and structure of stars and galaxies. Ultraviolet radiation focused on a mirror is reflected to a spectrometer that records the evidence of hydrogen, helium, carbon, and many other elements.

Ultraviolet Imaging Telescope (UIT)

Goddard Space Flight Center, Greenbelt, MD; Principal Investigator: Theodore P. Stecher
UIT takes the first extensive set of detailed ultraviolet photographs of the Universe, most of which has never been imaged in the ultraviolet. Light enters the telescope and is reflected by a primary mirror to a secondary mirror to a camera, which records images on film.

Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE)

The University of Wisconsin, Madison, WI; Principal Investigator: Arthur D. Code
The telescope observes the polarization (direction), photometry (brightness), and spectra of ultraviolet light from celestial objects. Light entering the telescope is focused by mirrors through polarizers and then onto a spectrometer and detectors that record data to give scientists clues about the shape and size of objects, the strength of magnetic fields, and the nature of gas and dust between the stars.

Broad Band X-Ray Telescope (BBXRT)

Goddard Space Flight Center, Greenbelt, MD; Principal Investigator: Peter J. Serlemitsos
BBXRT explores violent events such as exploding stars or matter and light being consumed by a black hole. Black holes may exist in the centers of galaxies. Two telescope mirrors focus X-rays onto detectors that record evidence of iron, oxygen, silicon, and other heavy elements found in the objects.

On-Orbit Crew

Commander: Vance D. Brand
Pilot: Guy S. Gardner
Mission Specialists: John M. (Mike) Lounge, Jeffrey A. Hoffman, Robert A.R. Parker
Payload Specialists: Samuel T. Durrance, Ronald A. Parise

Mission Parameters

Launch Date: April 1990
Mission Duration: 10 days
Altitude: 190 n.mi. (354 km)
Payload Weight: 30,948 lb (14,038 kg)

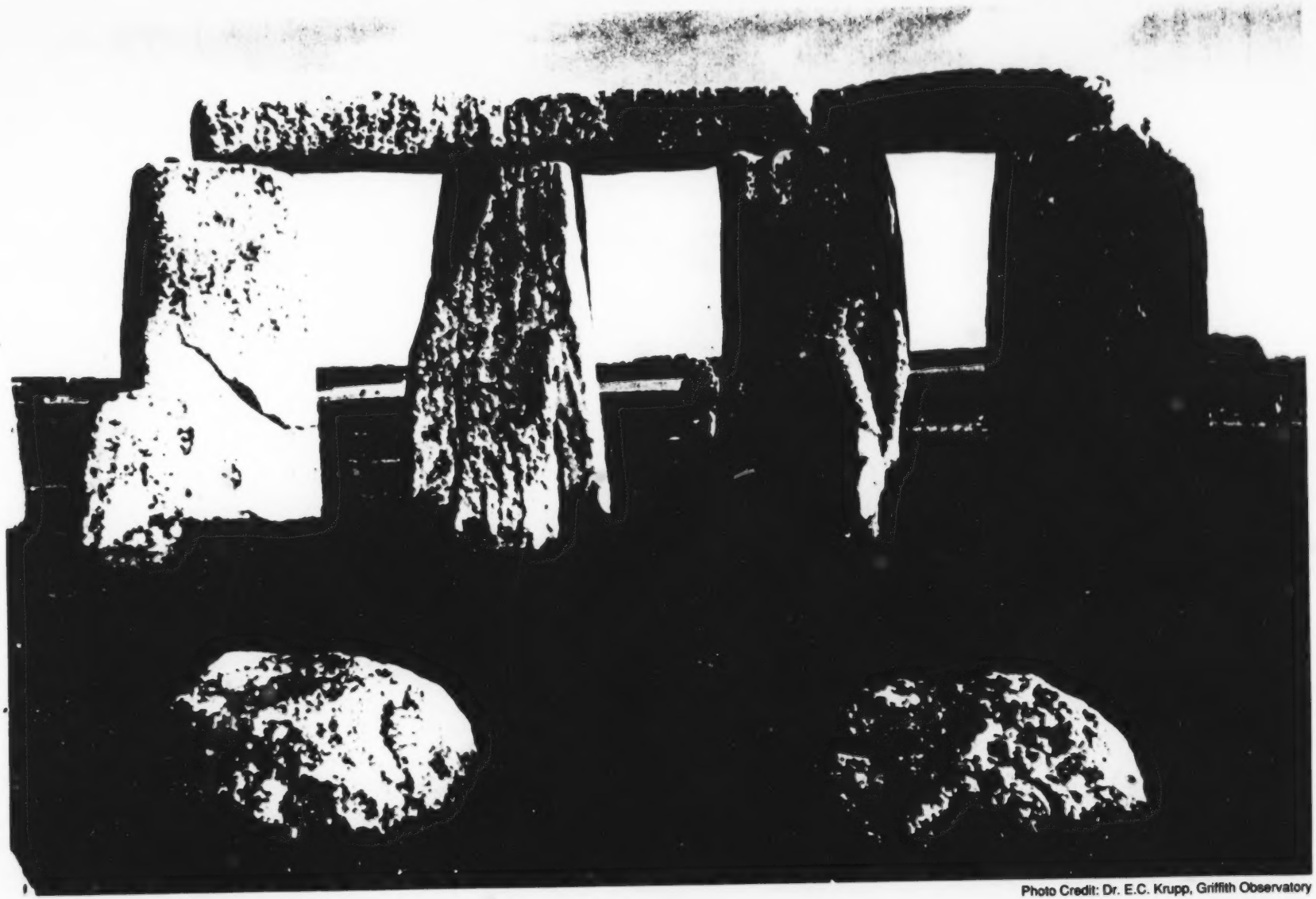

Photo Credit: Dr. E.C. Krupp, Griffith Observatory

43 **Stonehenge**

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Stonehenge

Astronomy is an ancient science practiced since the earliest recorded times. Evidence of these studies can be found in many parts of the world. **Stonehenge**, in Wiltshire, England, may have been an observatory or calendar built by early astronomers during three periods ranging from about 2500 B.C. to about 1700 B.C.

The monument consists of a complicated arrangement of stones, trenches, and holes arranged in concentric circles. Some of the stones are aligned with the directions of the Sun during its rising and setting at the vernal (spring) and autumnal (fall) **equinoxes.**

The Whipple Observatory

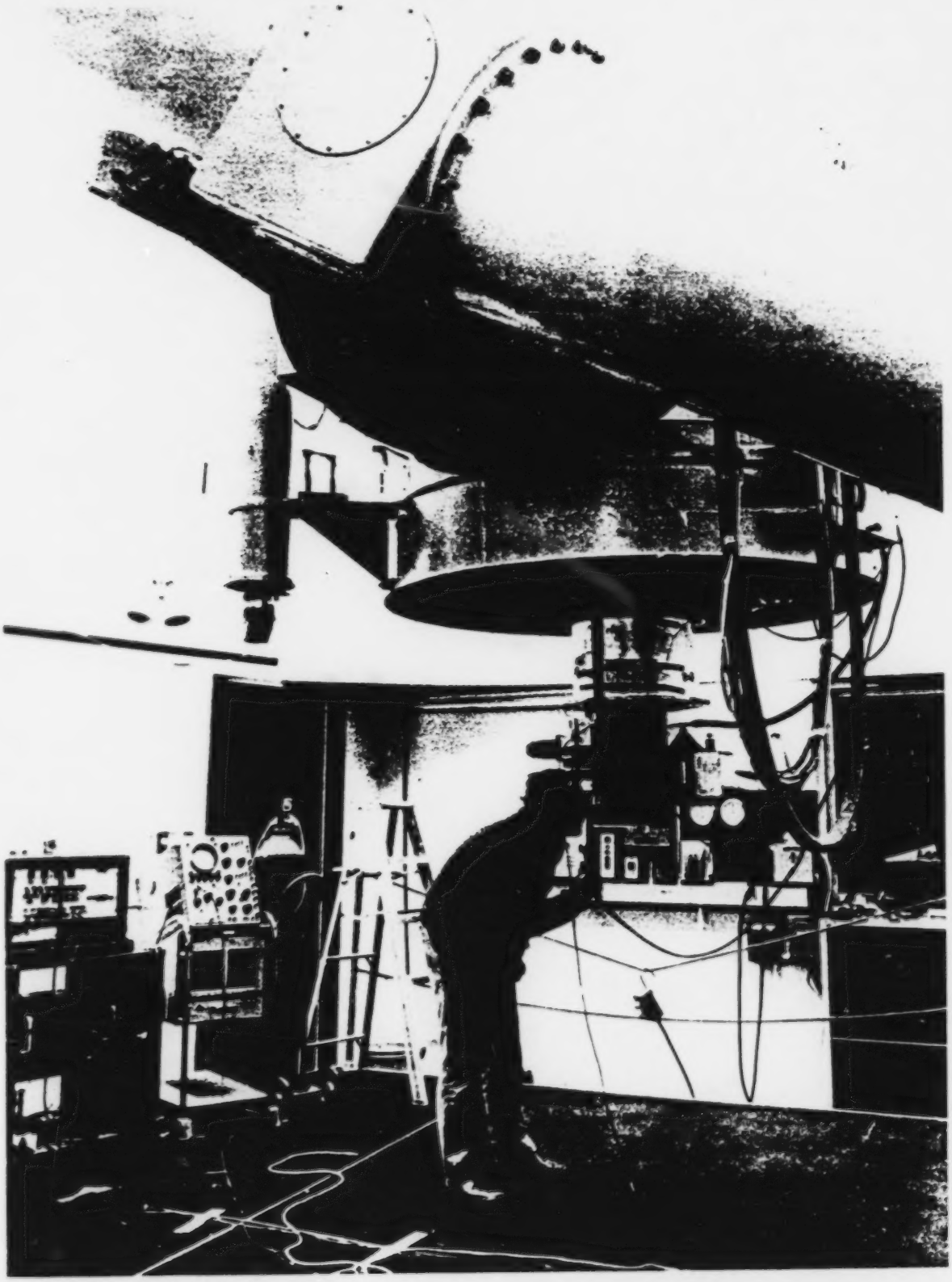

Photo Credit: Smithsonian Astrophysical Observatory

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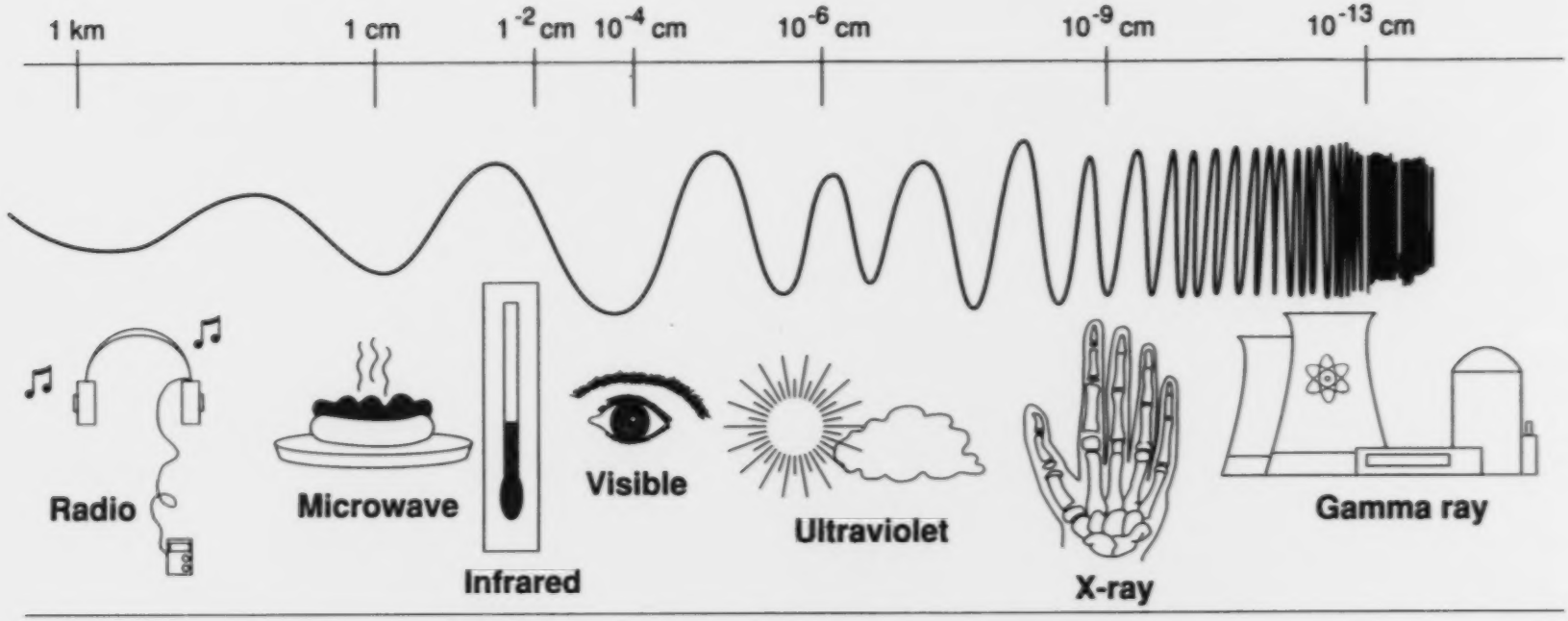
The Whipple Observatory

Over thousands of years, astronomers have progressed from searching the skies with the naked eye to using giant telescopes on mountaintops. They have transcended the atmosphere with instruments in balloons, rockets, satellites, and the Space Shuttle.

Whether on Earth or in space, all these scientists use instruments to collect light from celestial objects. By analyzing this light, they learn more about the size, shape, and chemical makeup of the targets being observed.

The photograph shown here is of an optical telescope at the Whipple Observatory, located on Mt. Hopkins, near Tucson, Arizona. Whipple Observatory is named after planetary expert Fred Lawrence Whipple and is part of the Smithsonian Astrophysical Observatory in Cambridge, Massachussetts. Astronomers at Whipple Observatory use a variety of instruments to research stars, planets, and objects beyond the Milky Way Galaxy. In addition, they study the Sun and monitor the health of Earth and its atmosphere.

The Electromagnetic Spectrum



The Electromagnetic Spectrum

For hundreds of years, scientists believed that light energy was made up of tiny particles which they called "corpuscles." In the 1600s, researchers observed that light energy also had many characteristics of waves. Modern scientists know that all energy is both particles, which they call **photons**, and waves.

Photons travel in **electromagnetic waves.** These waves travel at different **frequencies**, but all travel at the speed of light. The **electromagnetic spectrum** is the range of wave frequencies from low frequencies (below visible light) to high frequencies (above visible light).

The **radio wave** category includes radio and television waves. These low-energy waves bounce off many materials. AM waves bounce off the ionosphere and are reflected back to Earth. FM and television waves bounce off satellites for long-distance transmission.

Microwaves pass through some materials but are absorbed by others. In a microwave oven, the energy passes through the glass and is absorbed by the moisture in the food. The food cooks, but the glass container is not affected.

Like other wavelengths, **infrared** or heat waves are more readily absorbed by some materials than by others. Dark materials absorb infrared waves while light materials reflect them. The Sun emits infrared waves, heating the Earth and making plant and animal life possible.

Visible light waves are the very smallest part of the spectrum and are the only frequencies visible to the human eye. Colors are different frequencies within this category, ranging from the red wavelengths, which are just above the invisible infrared, to violet. Most of the Sun's energy is emitted as visible light.

The Sun also emits many **ultraviolet** waves. High-frequency ultraviolet wavelengths from the Sun cause sunburn.

X-rays can penetrate muscle and tissue but are blocked by bone, making medical and dental X-ray photographs possible.

Gamma-ray waves, the highest frequency waves, are more powerful than X-rays and are used to kill cancerous cells.

The atmosphere protects Earth from dangerous ultraviolet, X-ray, and gamma-ray radiation.

Why They Became Astronomers

Jeff Hoffman

I've been interested in astronomy as long as I can remember. When I was growing up in New York City, I went to the planetarium and learned all I could about the stars and planets. There was something intriguing about researching things too far away to touch. You could only use powerful telescopes to look at the light coming from them. We dreamed that we might someday travel into space, at least to the moon and planets, but that was the 1950s, and satellites hadn't been launched into space, much less people. As I went through high school and college, I studied a lot of mathematics and science, especially physics. Before becoming an astronaut, my work in astronomy involved putting telescopes into space to look at X-rays, gamma rays, and other radiation that doesn't penetrate the atmosphere. We put these telescopes up in high-flying balloons, rockets, and satellites, which intrigued me.

It was exciting because we were studying radiation that human beings had never seen before. Each new telescope put into space was almost guaranteed to make exciting new discoveries. Eventually, scientists were able to work on the Space Shuttle, and I was lucky enough to be selected to become an astronaut. I made one spaceflight in 1985, and I'm looking forward to flying on Astro-1.

Ron Parise

I have always been interested in spaceflight and astronomy. As a child, I followed the early space program closely; I read books on stars and planets. Astronomy was fascinating to me because of the questions it brought to mind: "Does the Universe go on forever?" "If it doesn't go forever, what's on the other side of it?"

As a teenager, I was involved with an amateur astronomy group and made astronomical observations myself. When you make observations, you find that the seemingly unchanging, fixed objects in the sky are actually quite dynamic: their intensities change, their spectra change, their positions change – it's not a static Universe at all.

Another interesting thing is that astronomy is not an experimental science like physics, chemistry, or biology, in which you can perform an experiment to prove a theory. You can't do that because the astronomical objects are at such vast distances. We have to be content with observing the electromagnetic radiation that they emit.

That brings another challenge into the subject – trying to develop new ways of observing things. On the ground, if you want to know what's on the other side of a wall, you go and look. In astronomy, you may come up against dust or gas floating around the stars that prevents you from seeing something. You have to develop ways to see around or through that barrier. It is a challenge to develop techniques that we can use to put the puzzle together.

"How did the Universe actually get here in the first place?" "What was there before it?" "How do all of these stars, planets, and galaxies work?" These questions brought me into astronomy, and the Space Shuttle gives me the opportunity to go into space and look at wavelengths that have rarely been observed.

Sam Durrance

I don't know for certain why I became an astronomer. I was always curious about how things work, but I was not always interested in astronomy. In high school and shortly after, I preferred things like building sports racing cars.

I was always interested in the space program, however; and on July 20, 1969, when men landed on the moon, I decided that I wanted to be part of that excitement. I went to college and earned my bachelor's and master's degrees in physics. I went to graduate school to study astronomy and became involved in a number of space projects, such as launching a rocket-borne telescope to look at Venus and using the Pioneer Venus-orbiting spacecraft to study that planet. After that, I went to The Johns Hopkins University, where I work today, to develop space astronomy hardware.

My primary interest in astronomy is studying the formation of planets in our own solar system, and the formation of planets around other stars. One of Astro's objectives is to study planets in our solar system, so I feel fortunate to be a part of Astro-1.

I have helped develop one of the Astro-1 telescopes and get it ready for flight, and now I look forward to doing the observations in space.

Robert Parker

I don't remember ever making a conscious decision to become an astronomer. Early influences may have been related to a simple book on the myths associated with constellations that I received in the second or third grade and a much more involved book a couple of years later. In any case, by junior high school I had become fascinated by the books of Sir James Jeans who at that time was probably similar to Carl Sagan as a popularizer of astronomy.

The fact that my father was a physicist (astronomy is, after all, just a branch of physics) was also clearly a background influence; my twin brother is a nuclear physicist.

Resources

Audiovisual Materials and Kits

Adventures in Science: Light
Activity cards and supplies
Educational Insights
Dominguez Hills, CA 90220

Astronomy Overhead Transparencies
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062 Phone: 1-800-323-8368

Astronomy Study Prints
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062 Phone: 1-800-323-8368

Glow-in-the-Dark Celestial Chart. #298505
The Nature Company
P.O. Box 2310
Berkeley, CA 94702

Our Universe Spacekit
National Geographic Society, 1980
Accompanies *Our Universe* text.

"Seven Days in Space." Video. Available with Teacher's Guide, audio supplement (crew interviews), computer software.
Halcyon Films and Video
110 Beach Road
Kings Point, NY 11024
Phone: 1-800-426-0582

3-D Star Maps. Book and two sets of 3-D glasses #300582
The Nature Company
P.O. Box 2310
Berkeley, CA 94702

Star Chart
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062
Phone: 1-800-323-8368

Star Finder/Zodiac Dial
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062
Phone: 1-800-323-8368

Games

"Sky Challenger"
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062
Phone: 1-800-323-8368

"Stellar 23"
Hubbard Scientific
1946 Raymond Drive
North Brook, IL 60062
Phone: 1-800-323-8368

Organizations

American Astronomical Society
2000 Florida Avenue, NW
Washington, DC 20009
Phone: 202-328-2010

Aerospace Educational Development Program
6991 South Madison Way
Littleton, CO 80122
Phone: 303-694-6836

American Astronautical Society
6212 Old Keene Mill Court
Springfield, VA 22152
Phone: 703-866-0020

Astronomical Society of the Pacific
390 Ashton Avenue
San Francisco, CA 94112
Phone: 415-337-1100

The Planetary Society
65 North Catalina Avenue
Pasadena, CA 91106
Phone: 818-793-5100

Planetariums and Observatories

Griffith Observatory
2800 East Observatory Road
Los Angeles, CA 90027
Phone: 213-664-1181

Hansen Planetarium
15 S. State Street
Salt Lake City, UT 84111
Phone: 801-538-2098
Catalog and orders: 1-800-321-2369

Harvard-Smithsonian Center for Astrophysics
60 Garden Street
Cambridge, MA 02138
Phone: 617-495-7000

National Optical Astronomy Observatories
P.O. Box 26732
Tucson, AZ 85726-6732
Phone: 602-325-9204

Publications

Books

Apfel, Necia H. *Astronomy Projects for Young Scientists.* New York: Arco Publishing, Inc., 1984.

Baker, David. *Believe It Or Not — Space Facts.* Vero Beach, FL: Rourke Enterprises, 1988.

Bova, Ben. *Starflight and Other Improbabilities.* Philadelphia: Westminster Press, 1973.

Chaple, Glenn F., Jr. *Exploring With A Telescope.* New York: Venture Books, 1988.

Chartrand, Mark R. *Skyguide: A Field Guide for Amateur Astronomers.* Racine, WI: Golden Press, 1982.

Gallant, Roy A. *The Macmillan Book of Astronomy.* New York: Macmillan, 1986.

Jespersen, James, and Jane Fitz-Randolph. *From Quarks to Quasars.* New York: Atheneum Press, 1987.

Mitton, Jacqueline, and Simon Mitton. *Discovering Astronomy.* London: Stonehenge Press, 1982.

Byron Preiss, Ed. *The Universe.* New York: Bantam Books, 1987.

Provenzo, Eugene F., Jr., and Asterie Baker Provenzo. *Rediscovering Astronomy.* La Jolla, CA: Oak Tree Publications, Inc., 1980.

Rossie, John P. *Handbook for Aerospace Education.* Littleton, CO: Aerospace Educational Development Program, 1988.

Taylor, Ron. *The Invisible World.* New York: Facts on File Publications, 1985.

Zim, Herbert S. *Waves.* New York: Morrow, 1967.

Periodicals

Air and Space Magazine
Smithsonian Institution
P.O. Box 51244
Boulder, CO 80321-1244
Phone: 303-449-9609

Astronomy Magazine and *Astronomy Educator*
Kalmbach Publishing
21027 Crossroads Circle
P.O. Box 1612
Waukesha, WI 53187
Phone: 1-800-446-5489

Odyssey: Space Exploration and Astronomy for Young People
Astro Media Division
Kalmbach Publishing
21027 Crossroads Circle
P.O. Box 1612
Waukesha, WI 53187
Phone: 1-800-446-5489

Sky and Telescope
Sky Publishing Corporation
49 Bay State Road
Cambridge, MA 02138
Phone: 617-864-7360

NASA Educational Resources

NASA Spacelink: An Electronic Information System

NASA Spacelink is an information access system that allows individuals to log on and receive news about current NASA programs and activities and other space-related information, including historical and astronaut data, lesson plans and classroom activities, and even entire publications. Although primarily intended as a resource for teachers, anyone with a personal computer and modem can access the network.

Use the instructions that come with your modem and communications software when calling NASA Spacelink. The computer access number is 205-895-0028. The data word format is 8 bits, no parity, and 1 stop bit. Your computer may send carriage returns or line feeds, but not both. To log on as a first-time caller, enter the Username NEWUSER and the Password NEWUSER. The service is free, but you may have to pay long-distance phone charges. For more information, contact:

Spacelink Administrator
NASA Marshall Space Flight Center
Mail Code CA20
MSFC, AL 35812
Phone: 205-544-6527

NASA Educational Satellite Videoconferences

During the school year, a series of educational programs is delivered by satellite to teachers across the country. The content of each video conference varies, but all cover aeronautics or space science topics of interest to the educational community. The broadcasts are interactive; a number is flashed across the bottom of the screen, and viewers can call collect to ask questions or take part in a discussion. For further information, contact:

Videoconference Coordinator
NASA Aerospace Education Services Program
300 North Cordell
Oklahoma State University
Stillwater, OK 74078-0422
Phone: 405-744-7015

Mr. William D. Nixon
Educational Technology Branch
Educational Affairs Division
Code XE
NASA Headquarters
Washington, DC 20546
Phone: 202-453-8388

Central Operation of Resources for Educators (CORE)

CORE is a centralized mail-order audiovisual library for educators; no printed materials are available. Submit a written request on your school letterhead for a catalogue and order forms. Orders are processed for a small fee that includes the cost of the media. For more information, contact:

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
Phone: 216-774-1051, Ext. 293 or 294

Teacher Resource Center Network

To make information available to the educational community, the Educational Affairs Division has created the NASA Teacher Resource Center Network. Teacher Resource Centers (TRCs) contain a wealth of information for educators: publications, reference books, slides, audio cassettes, videocassettes, telelecture programs, computer programs, lesson plans and activities, and lists of publications available from government and nongovernment sources.

Because each NASA field center has its own areas of expertise, no two TRCs are exactly alike. Phone calls are welcome if you are unable to visit the TRC that serves your geographic area. The chart on the next page delineates the geographic regions and provides addresses.

For more information about Elementary and Secondary Programs

If you live in:	Center Education Programs Officer	Teacher Resource Center
Alaska Arizona California Hawaii Idaho Montana Nevada Oregon Utah Washington Wyoming	Mr. Garth A. Hull Chief, Educational Programs Branch Mail Stop T025 NASA Ames Research Center Moffett Field, CA 94035 Phone: 415-694-5543	NASA Ames Research Center Attn: Teacher Resource Center Mail Stop T025 Moffett Field, CA 94035 Phone: 415-694-3574
Connecticut Delaware District of Columbia Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	Mr. Elva Bailey Chief, Educational Programs Public Affairs Office (130) NASA Goddard Space Flight Center Greenbelt, MD 20771 Phone: 301-286-7207	NASA Goddard Space Flight Center Attn: Teacher Resource Laboratory Mail Code 130.3 Greenbelt, MD 20771 Phone: 301-286-8570
Colorado Kansas Nebraska New Mexico North Dakota Oklahoma South Dakota Texas	Mr. James D. Poindexter Educational Specialist Public Affairs Office (AP4) NASA Johnson Space Center Houston, TX 77058 Phone: 713-483-8624	NASA Johnson Space Center Attn: Teacher Resource Room Mail Code AP-4 Houston, TX 77058 Phone: 713-483-8696
Florida Georgia Puerto Rico Virgin Islands	Mr. Raymond R. Corey Chief, Education and Awareness Branch Mail Code PA-EAB NASA Kennedy Space Center Kennedy Space Center, FL 32899 Phone: 407-867-4444	NASA Kennedy Space Center Attn: Educators Resources Laboratory Mail Code ERL Kennedy Space Center, FL 32899 Phone: 407-867-4090

Kentucky North Carolina South Carolina Virginia West Virginia	Mr. Roger Hathaway Education Specialist Mail Stop 154 NASA Langley Research Center Hampton, VA 23665-5225 Phone: 804-864-3312	NASA Langley Research Center Attn: Teacher Resource Center Mail Stop 146 Hampton, VA 23665-5225 Phone: 804-864-3293
Illinois Indiana Michigan Minnesota Ohio Wisconsin	Dr. Lynn Bondurant Chief, Educational Services Office Mail Stop 7-4 NASA Lewis Research Center 21100 Brookpark Road Cleveland, OH 44135 Phone: 216-433-5583	NASA Lewis Research Center Attn: Teacher Resource Center Mail Stop 8-1 21100 Brookpark Road Cleveland, OH 44135 Phone: 216-433-2016 or 2017
Alabama Arkansas Iowa Louisiana Missouri Tennessee	Mr. Jeffrey Ehmen Education Officer Public Affairs Office (CA20) NASA Marshall Space Flight Center MSFC, AL 35812 Phone: 205-544-6531	Alabama Space and Rocket Center Attn: NASA Teacher Resource Center Huntsville, AL 35807 Phone: 205-544-5812
Mississippi	Education Officer Public Affairs Office NASA John C. Stennis Space Center Stennis Space Center, MS 39529 Phone: 601-688-3341	NASA John C. Stennis Space Center Attn: Teacher Resource Center Building 1200 Stennis Space Center, MS 39529 Phone: 601-688-3338
The Jet Propulsion Laboratory serves inquiries related to space and planetary exploration and other JPL activities.	Mr. Philipp D. Neuhauser Manager, Education Mail Code 180-205 Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91109 Phone: 818-354-8592	Jet Propulsion Laboratory Attn: Teacher Resource Center JPL Educational Outreach Mail Stop CS-530 Pasadena, CA 91109 Phone: 818-354-6916

Where to Obtain Materials

Concept 1

prism or diffraction grating:

FSC Educational
905 Hickory Lane
P.O. Box 8101
Mansfield, OH 44905
Phone: 1-800-225-FREY

Sargent-Welch
7400 N. Linder Avenue
P.O. Box 1026
Skokie, IL 60077-1026
Phone: 1-800-SARGENT

Concept 2

blueprint paper:

local print shop

Concept 3

color filters:

Colored plastic wrap or cellophane or color filters from local camera shop

Optical kits containing color filters may be obtained from scientific suppliers listed above.

Concept 5

dilute sulfuric acid:

Sargent-Welch
7400 N. Linder Avenue
P.O. Box 1026
Skokie, IL 60077-1026
1-800-SARGENT

sodium thiosulfate or sodium hyposulfite:
local camera shop or scientific supply listed above

Glossary

accretion disk - a rapidly spinning disk of matter that has been drawn from a primary star in a close binary star system. The matter does not fall directly onto the compact companion, which may be a neutron star, white dwarf, or black hole, but swirls down onto the smaller body in the form of a disk. Gradually the matter in the disk heats up and spirals onto the smaller body emitting large quantities of X-ray and ultraviolet radiation.

binary star system - two bodies revolving around a common center of gravity. Usually consists of a primary star and a compact companion, such as a white dwarf, neutron star, or black hole.

black hole - a point in space where scientists believe that gravitational forces are so intense that neither matter nor light escapes. Possibly the result of the collapse of a massive star.

Broad Band X-Ray Telescope (BBXRT) - an X-ray telescope developed at Goddard Space Flight Center. Uses mirrors and advanced solid-state detectors as spectrometers to examine the chemistry, structure, and dynamics of a source. BBXRT will fly on the Astro-1 mission scheduled for spring of 1990.

concave - curving inward.

continuous spectrum - a spectrum of radiation in which there are no lines of emission or absorption. Emissions from hot, dense matter will produce a continuous spectrum.

convex - bulging outward.

crest - the highest point, e.g., the highest point of a wave.

diffraction grating - a plate etched or ruled with a large number of grooves. Acts to disperse light into different wavelengths, thus producing a visible spectrum.

electromagnetic spectrum - the full range of electromagnetic radiation from the longest to the shortest wavelengths. Usually divided into seven sections: radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma-ray radiation.

frequency - the number of wave crests or troughs passing a set point in a unit of time.

gamma rays - shortest, most energetic form of electromagnetic radiation.

galaxy - collections of millions of stars mixed with gas and dust. Galaxies have three basic forms: spiral, elliptical, and irregular.

Hertz (Hz) - a measure of frequency equalling one cycle per second.

Hertzsprung-Russell Diagram (H-R Diagram) - a diagram showing the relationship between the temperature, magnitude, mass, and color of stars.

Hopkins Ultraviolet Telescope (HUT) - a telescope and spectroscope developed at The Johns Hopkins University. Studies the ultraviolet spectra of faint astronomical objects. HUT, along with two other ultraviolet instruments and one X-ray instrument, will fly on the Astro-1 mission.

infra - prefix from the Latin meaning "below," especially as in a scale or series.

infrared radiation - radiation just beyond the red end of the visible portion of the electromagnetic spectrum. Most infrared radiation is blocked by the atmosphere, but enough solar infrared penetrates to heat Earth's surface. Infrared radiation is used to make maps of Earth's surface.

interstellar medium - matter existing between the stars, consisting mainly of hydrogen and flecks of dust. Helium may also be a major component.

light-year - the distance that light or any form of electromagnetic radiation can travel in 1 year, approximately 5.9×10^{12} mi (9.5×10^{12} km).

magnitude - the brightness of stars and other celestial objects. The greater the brightness, the lower the magnitude.

main sequence stars - the band on the Hertzsprung-Russell Diagram where most stars are found. It runs from the hot, blue stars in the upper left to the cool, red stars on the lower right.

mass - the amount of matter in an object.

microwave radiation - radiation less energetic than infrared and more energetic than radio waves. Used for radar and to cook food.

neutron star - a star that has undergone gravitational collapse, forming the tiniest, densest object known. A neutron star has a mass comparable to the Sun but is collapsed into an object about 12.4 mi (20 km) in diameter, resulting in matter so dense that a teaspoonful could weigh a billion tons.

photon - a packet of electromagnetic radiation.

prism - a transparent object with five sides and triangular ends that can be used to break visible light into its component colors.

radiation - a flow of energy, usually defined as photons, or packets of energy, traveling in waves.

radio waves - the longest and least energetic form of energy on the electromagnetic spectrum.

reflector telescope - a telescope that collects and focuses light with a mirror. Also called a reflecting telescope.

refractor telescope - a telescope that collects and focuses light by means of a lens. Also called a refracting telescope.

scientific notation - a way to write very large or very small numbers. Substitutes powers of 10 for strings of zeros. For example, 561,000,000,000 = 5.61×10^{11} and 0.0000000079 = 7.9×10^{-9}.

spectra - plural form of spectrum.

spectrum - the range of electromagnetic energy emitted or absorbed by a substance.

spiral arms - the parts of a spiral galaxy where new stars are most likely to be formed. The arms are concentrated areas of gas and dust.

star - a celestial object that generates energy by means of nuclear fusion reactions.

supernova - the explosion of a giant star; its last stage of evolution.

supernova remnant - the expanding shell of gas and matter blown off in a supernova. Frequently are strong sources of X-ray and ultraviolet emissions.

ultra - prefix meaning "beyond."

Ultraviolet Imaging Telescope (UIT) - a combination telescope and camera developed at Goddard Space Flight Center. Takes ultraviolet pictures of celestial objects. Will fly on the Astro-1 mission in the spring of 1990.

ultraviolet radiation - the energy range just beyond the violet end of the visible spectrum. Most ultraviolet radiation is blocked by Earth's atmosphere, but some solar ultraviolet penetrates and aids in plant photosynthesis. Ultraviolet radiation has both positive and negative effects on humans: some ultraviolet helps produce vitamin D; too much can burn skin.

white dwarfs - faint stars that have undergone gravitational collapse in their final stages of evolution. White dwarfs, which emit most of their radiation in the ultraviolet, are sometimes found as companions to larger stars in binary star systems.

white light - radiation in the electromagnetic spectrum that is visible to human beings.

Wisconsin Photo-Polarimeter Experiment (WUPPE) - an ultraviolet instrument developed at the University of Wisconsin. Measures the polarization and intensity of ultraviolet radiation from celestial objects and the interstellar medium. Will fly on the Astro-1 mission.

X-rays - energetic form of radiation between ultraviolet radiation and gamma rays. Because they are energetic enough to penetrate muscle and tissue but not bone, X-rays are used to examine bones and teeth.

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Astro-1 Teacher's Guide: Seeing in a New Light

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SA – Strongly Agree
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